



## **Module Manual**

Master of Science (M.Sc.)

## **Renewable Energies**

Cohort: Winter Term 2025

Updated: 1st June 2026



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## Program description

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### Content

In recent decades energy consumption and the associated man-made repercussions on the environment have steadily increased and the (perceived) security of supplies has decreased. This trend can be expected to continue. Increased use of renewable energies - these being hydroelectric, wind and solar power, biomass and geothermal energy - in the electricity, heating and fuel market can make a major contribution toward facing these challenges.

On completing this master's program in Renewable Energies, graduates are able to explain and assess the possibilities of and limits to the provision of energy for the heating, electricity and fuel market by the renewable energy sources sun, geothermal heat and planetary gravitation and movement. These explanations are primarily from the technical but also from the economic and ecological viewpoint. Graduates can provide an overview of the physical and chemical characteristics of renewable energy sources, have understood the fundamental technical principles of their use and can assess the resulting technical and technological requirements of the requisite conversion plant technology. They can also assess the plant and system technology and the economic and ecological basics of the individual options for renewable energy supply. Graduates have an overview of aspects for integration of plants and systems based on renewable energies into the existing energy system - both in Germany and in non-European countries. Furthermore they can discuss issues of energy storage and the development of renewable energy projects with experts. This specialized knowledge and related skills also enable graduates to take up a position on current energy industry issues on a sound and ideology-free basis. As a result of this master's program they are qualified to advise interested parties in a professional capacity or to formulate independently problems and objectives for new application - or research-oriented tasks.

A further in-depth specialization, as a part of the master's program, in the renewable energy system biomass, solar or wind power is possible. Thus, the program provides a comprehensive knowledge on practically all options of renewable energy supply, it's utilization in the energy system - taking existing structures into account - and on selected associated technical, economic and ecological aspects.

### Career prospects

The successful completion of the Master's program "Renewable Energies" enables graduates to hold leading positions in the engineering labor market. Typical fields of activities can be found in energy suppliers, energy consultants, project developers, as well as technical authorities in the renewable energy industry. Furthermore, there is the possibility of engaging in activities as a research assistant with the aim of doctoral degree.

### Learning target

Graduates of the Master's program "Renewable Energies" will be able to transfer their acquired knowledge of their engineering and scientific study into practice and to broaden it independently if necessary. They can analyse problems using scientific methods to find an engineering solution, even if the problems are "open" or incomplete defined. They are able to work independently in power engineering and in related disciplines. They can apply, critically analyse and further develop new practices and procedures to solve technical and conceptual issues. Graduates are also qualified to develop projects in the field of "Renewable Energies" with an emphasis on:

- Wind energy
- Photovoltaics,
- Hydropower,
- Ocean energy,
- Biomass and
- Geothermal

and to define and schedule these with respect to necessary clarifications and available information.

### Program structure

The technical contents of the master are structured as follows:

- Modules of the core skills:
  - technical fundamentals of usage of renewable energy sources,
  - project evaluation, economy and sustainability,
  - electrical power engineering,
  - non- technical supplementary courses,
- modules of specialization:
  - bioenergy systems,
  - solar energy systems,
  - wind energy systems,
- Master's thesis.

The choice of one specialization is compulsory. Within one specialization courses have to be selected from a catalog of elective courses.

Despite of individual freedom in the choice of courses within the specialization, courses in the core qualification are compulsory for all students. With these courses a balance of formal and practical course content in theory and application of the learning outcomes is ensured.

Non-technical supplementary courses and courses in operation and management provide more flexibility in the individual design of the curriculum and ensure a linkage between technical and business knowledge. These courses can be chosen from the general catalog of the TUHH.

The master thesis with a share of 25% describe the remaining part of the curriculum.

Note: Within the specialization "Solar Energy Systems", students have been given the opportunity to study abroad at the "University of Jordan" in Amman, Jordan. Within this foreign stay, additional modules in the field of "solar energy systems" can be chosen. The earned credits are recognized at TUHH by agreement.

## Core Qualification

Within the core qualification of the Master "Renewable energies" the students gain knowledge about the possibilities and limitations of energy supply from the various renewable energy sources for the heat, electricity and fuel market.

Basis for this aim are on one hand the courses of consecutive Bachelor courses and on the other hand continuing and applied courses in the field of electrical engineering, thermodynamics and fluid mechanics.

Continuing to these courses the different principles for the use of renewable energies and the resulting requirements on the corresponding conversion plant technology are presented, primarily from a technical perspective. Nonetheless, this knowledge is linked to economic and environmental context, to understand and to evaluate the integration of renewable energy applications in energy systems - both in Germany, Europe and countries outside Europe. Furthermore, energy storage opportunities are discussed in this context.

Within the module "Projects and their Assessment", non-technical aspects of the implementation of projects especially in the field of renewable energies are considered, to provide background information in the legal and economic energy implementation of renewable energy applications.

### Module M0523: Business & Management

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|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| <b>Module Responsible</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Prof. Matthias Meyer                                                                 |
| <b>Admission Requirements</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Successful completion of the modul "Foundations of Management"                       |
| <b>Recommended Previous Knowledge</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | None                                                                                 |
| <b>Educational Objectives</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | After taking part successfully, students have reached the following learning results |
| <b>Professional Competence</b><br><i>Knowledge</i> <ul style="list-style-type: none"> <li>• Students are able to find their way around selected special areas of management within the scope of business management.</li> <li>• Students are able to explain basic theories, categories, and models in selected special areas of business management.</li> <li>• Students are able to interrelate technical and management knowledge.</li> </ul><br><i>Skills</i> <ul style="list-style-type: none"> <li>• Students are able to apply basic methods in selected areas of business management.</li> <li>• Students are able to explain and give reasons for decision proposals on practical issues in areas of business management.</li> </ul><br><b>Personal Competence</b><br><i>Social Competence</i> <ul style="list-style-type: none"> <li>• Students are able to communicate in small interdisciplinary groups and to jointly develop solutions for complex problems</li> </ul><br><i>Autonomy</i> <ul style="list-style-type: none"> <li>• Students are capable of acquiring necessary knowledge independently by means of research and preparation of material.</li> </ul> |                                                                                      |
| <b>Workload in Hours</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Depends on choice of courses                                                         |
| <b>Credit points</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 6                                                                                    |

### Courses

**Information regarding lectures and courses can be found in the corresponding module handbook published separately.**

| Module M0524: Non-technical Courses for Master     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|----------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Module Responsible</b>                          | Dagmar Richter                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Admission Requirements</b>                      | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Recommended Previous Knowledge</b>              | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Educational Objectives</b>                      | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Professional Competence</b><br><i>Knowledge</i> | <p><b>The Nontechnical Academic Programms (NTA)</b></p> <p>imparts skills that, in view of the TUHH's training profile, professional engineering studies require but are not able to cover fully. Self-reliance, self-management, collaboration and professional and personnel management competences. The department implements these training objectives in its <b>teaching architecture</b>, in its <b>teaching and learning arrangements</b>, in <b>teaching areas</b> and by means of teaching offerings in which students can qualify by opting for <b>specific competences</b> and a <b>competence level</b> at the Bachelor's or Master's level. The teaching offerings are pooled in two different catalogues for nontechnical complementary courses.</p> <p><b>The Learning Architecture</b></p> <p>consists of a cross-disciplinarily study offering. The centrally designed teaching offering ensures that courses in the nontechnical academic programms follow the specific profiling of TUHH degree courses.</p> <p>The learning architecture demands and trains independent educational planning as regards the individual development of competences. It also provides orientation knowledge in the form of "profiles".</p> <p>The subjects that can be studied in parallel throughout the student's entire study program - if need be, it can be studied in one to two semesters. In view of the adaptation problems that individuals commonly face in their first semesters after making the transition from school to university and in order to encourage individually planned semesters abroad, there is no obligation to study these subjects in one or two specific semesters during the course of studies.</p> <p><b>Teaching and Learning Arrangements</b></p> <p>provide for students, separated into B.Sc. and M.Sc., to learn with and from each other across semesters. The challenge of dealing with interdisciplinarity and a variety of stages of learning in courses are part of the learning architecture and are deliberately encouraged in specific courses.</p> <p><b>Fields of Teaching</b></p> <p>are based on research findings from the academic disciplines cultural studies, social studies, arts, historical studies, communication studies, migration studies and sustainability research, and from engineering didactics. In addition, from the winter semester 2014/15 students on all Bachelor's courses will have the opportunity to learn about business management and start-ups in a goal-oriented way.</p> <p>The fields of teaching are augmented by soft skills offers and a foreign language offer. Here, the focus is on encouraging goal-oriented communication skills, e.g. the skills required by outgoing engineers in international and intercultural situations.</p> <p><b>The Competence Level</b></p> <p>of the courses offered in this area is different as regards the basic training objective in the Bachelor's and Master's fields. These differences are reflected in the practical examples used, in content topics that refer to different professional application contexts, and in the higher scientific and theoretical level of abstraction in the B.Sc.</p> <p>This is also reflected in the different quality of soft skills, which relate to the different team positions and different group leadership functions of Bachelor's and Master's graduates in their future working life.</p> <p><b>Specialized Competence (Knowledge)</b></p> <p>Students can</p> <ul style="list-style-type: none"> <li>• explain specialized areas in context of the relevant non-technical disciplines,</li> <li>• outline basic theories, categories, terminology, models, concepts or artistic techniques in the disciplines represented in the learning area,</li> <li>• different specialist disciplines relate to their own discipline and differentiate it as well as make connections,</li> <li>• sketch the basic outlines of how scientific disciplines, paradigms, models, instruments, methods and forms of representation in the specialized sciences are subject to individual and socio-cultural interpretation and historicity,</li> <li>• Can communicate in a foreign language in a manner appropriate to the subject.</li> </ul> <p><i>Skills</i></p> <p><b>Professional Competence (Skills)</b></p> <p>In selected sub-areas students can</p> <ul style="list-style-type: none"> <li>• apply basic and specific methods of the said scientific disciplines,</li> <li>• question a specific technical phenomena, models, theories from the viewpoint of another, aforementioned specialist discipline,</li> <li>• to handle simple and advanced questions in aforementioned scientific disciplines in a successful manner,</li> <li>• justify their decisions on forms of organization and application in practical questions in contexts that go beyond the technical relationship to the subject.</li> </ul> |

|                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|-----------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>Personal Competence</b><br/> <i>Social Competence</i></p> | <p><b>Personal Competences (Social Skills)</b></p> <p>Students will be able</p> <ul style="list-style-type: none"> <li>• to learn to collaborate in different manner,</li> <li>• to present and analyze problems in the abovementioned fields in a partner or group situation in a manner appropriate to the addressees,</li> <li>• to express themselves competently, in a culturally appropriate and gender-sensitive manner in the language of the country (as far as this study-focus would be chosen),</li> <li>• to explain nontechnical items to auditorium with technical background knowledge.</li> </ul>                                         |
|                                                                 | <p><i>Autonomy</i></p> <p><b>Personal Competences (Self-reliance)</b></p> <p>Students are able in selected areas</p> <ul style="list-style-type: none"> <li>• to reflect on their own profession and professionalism in the context of real-life fields of application</li> <li>• to organize themselves and their own learning processes</li> <li>• to reflect and decide questions in front of a broad education background</li> <li>• to communicate a nontechnical item in a competent way in written form or verbally</li> <li>• to organize themselves as an entrepreneurial subject country (as far as this study-focus would be chosen)</li> </ul> |
| <b>Workload in Hours</b>                                        | Depends on choice of courses                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Credit points</b>                                            | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

## Courses

**Information regarding lectures and courses can be found in the corresponding module handbook published separately.**

| Module M1294: Bioenergy                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                            |         |                                |
|--------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|---------|--------------------------------|
| Courses                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                            |         |                                |
| Title                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Typ                        | Hrs/wk  | CP                             |
| Biofuels Process Technology (L0061)                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Lecture                    | 1       | 1                              |
| Biofuels Process Technology (L0062)                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Recitation Section (small) | 1       | 1                              |
| World Market for Commodities from Agriculture and Forestry (L1769) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Lecture                    | 1       | 1                              |
| Thermal Biomass Utilization (L1767)                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Lecture                    | 2       | 2                              |
| Thermal Biomass Utilization (L2386)                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Practical Course           | 1       | 1                              |
| Module Responsible                                                 | Prof. Martin Kaltschmitt                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |         |                                |
| Admission Requirements                                             | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                            |         |                                |
| Recommended Previous Knowledge                                     | none                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                            |         |                                |
| Educational Objectives                                             | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                            |         |                                |
| Professional Competence                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                            |         |                                |
| Knowledge                                                          | Students are able to reproduce an in-depth outline of energy production from biomass, aerobic and anaerobic waste treatment processes, the gained products and the treatment of produced emissions.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |         |                                |
| Skills                                                             | Students can apply the learned theoretical knowledge of biomass-based energy systems to explain relationships for different tasks, like dimesioning and design of biomass power plants. In this context, students are also able to solve computational tasks for combustion, gasification and biogas, biodiesel and bioethanol use.                                                                                                                                                                                                                                                                                                                                                       |                            |         |                                |
| Personal Competence                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                            |         |                                |
| Social Competence                                                  | Students can participate in discussions to design and evaluate energy systems using biomass as an energy source.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                            |         |                                |
| Autonomy                                                           | Students can independently exploit sources with respect to the emphasis of the lectures. They can choose and aquire the for the particular task useful knowledge. Furthermore, they can solve computational tasks of biomass-based energy systems independently with the assistance of the lecture. Regarding to this they can assess their specific learning level and can consequently define the further workflow.                                                                                                                                                                                                                                                                     |                            |         |                                |
| Workload in Hours                                                  | Independent Study Time 96, Study Time in Lecture 84                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |         |                                |
| Credit points                                                      | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                            |         |                                |
| Course achievement                                                 | Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Bonus                      | Form    | Description                    |
|                                                                    | Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | None                       | Subject | theoretical and practical work |
| Examination                                                        | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                            |         |                                |
| Examination duration and scale                                     | 3 hours written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                            |         |                                |
| Assignment for the Following Curricula                             | Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory<br>Energy Systems: Specialisation Energy Systems: Elective Compulsory<br>International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory<br>Renewable Energies: Core Qualification: Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory |                            |         |                                |



| Course L0061: Biofuels Process Technology |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|-------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Hrs/wk</b>                             | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>CP</b>                                 | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Workload in Hours</b>                  | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Lecturer</b>                           | Prof. Oliver Lüdtke                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Language</b>                           | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Cycle</b>                              | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Content</b>                            | <ul style="list-style-type: none"> <li>• General introduction</li> <li>• What are biofuels?</li> <li>• Markets &amp; trends</li> <li>• Legal framework</li> <li>• Greenhouse gas savings</li> <li>• Generations of biofuels <ul style="list-style-type: none"> <li>◦ first-generation bioethanol <ul style="list-style-type: none"> <li>▪ raw materials</li> <li>▪ fermentation distillation</li> </ul> </li> <li>◦ biobutanol / ETBE</li> <li>◦ second-generation bioethanol <ul style="list-style-type: none"> <li>▪ bioethanol from straw</li> </ul> </li> <li>◦ first-generation biodiesel <ul style="list-style-type: none"> <li>▪ raw materials</li> <li>▪ Production Process</li> <li>▪ Biodiesel &amp; Natural Resources</li> </ul> </li> <li>◦ HVO / HEFA</li> <li>◦ second-generation biodiesel <ul style="list-style-type: none"> <li>▪ Biodiesel from Algae</li> </ul> </li> </ul> </li> <li>• Biogas as fuel <ul style="list-style-type: none"> <li>◦ the first biogas generation <ul style="list-style-type: none"> <li>▪ raw materials</li> <li>▪ fermentation</li> <li>▪ purification to biomethane</li> </ul> </li> <li>◦ Biogas second generation and gasification processes</li> </ul> </li> <li>• Methanol / DME from wood and Tall oil ©</li> </ul> |
| <b>Literature</b>                         | <ul style="list-style-type: none"> <li>• Skriptum zur Vorlesung</li> <li>• Drapcho, Nhuan, Walker; Biofuels Engineering Process Technology</li> <li>• Harwardt; Systematic design of separations for processing of biorenewables</li> <li>• Kaltschmitt; Hartmann; Energie aus Biomasse: Grundlagen, Techniken und Verfahren</li> <li>• Mousdale; Biofuels - Biotechnology, Chemistry and Sustainable Development</li> <li>• VDI Wärmeatlas</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

| Course L0062: Biofuels Process Technology |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|-------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                | Recitation Section (small)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Hrs/wk</b>                             | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>CP</b>                                 | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Workload in Hours</b>                  | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Lecturer</b>                           | Prof. Oliver Lüdtke                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Language</b>                           | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Cycle</b>                              | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Content</b>                            | <ul style="list-style-type: none"> <li>• Life Cycle Assessment <ul style="list-style-type: none"> <li>◦ Good example for the evaluation of CO<sub>2</sub> savings potential by alternative fuels - Choice of system boundaries and databases</li> </ul> </li> <li>• Bioethanol production <ul style="list-style-type: none"> <li>◦ Application task in the basics of thermal separation processes (rectification, extraction) will be discussed. The focus is on a column design, including heat demand, number of stages, reflux ratio ...</li> </ul> </li> <li>• Biodiesel production <ul style="list-style-type: none"> <li>◦ Procedural options for solid / liquid separation, including basic equations for estimating power, energy demand, selectivity and throughput</li> </ul> </li> <li>• Biomethane production <ul style="list-style-type: none"> <li>◦ Chemical reactions that are relevant in the production of biofuels, including equilibria, activation energies, shift reactions</li> </ul> </li> </ul> |
| <b>Literature</b>                         | Skriptum zur Vorlesung                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

| Course L1769: World Market for Commodities from Agriculture and Forestry |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|--------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                               | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Hrs/wk</b>                                                            | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>CP</b>                                                                | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Workload in Hours</b>                                                 | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Lecturer</b>                                                          | Prof. Michael Köhl, Bernhard Chilla                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Language</b>                                                          | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Cycle</b>                                                             | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Content</b>                                                           | <p>1) Markets for Agricultural Commodities</p> <p>What are the major markets and how are markets functioning</p> <p>Recent trends in world production and consumption.</p> <p>World trade is growing fast. Logistics. Bottlenecks.</p> <p>The major countries with surplus production</p> <p>Growing net import requirements, primarily of China, India and many other countries.</p> <p>Tariff and non-tariff market barriers. Government interferences.</p> <p>2) Closer Analysis of Individual Markets</p> <p>Thomas Mielke will analyze in more detail the global vegetable oil markets, primarily palm oil, soya oil, rapeseed oil, sunflower oil. Also the raw material (the oilseed) as well as the by-product (oilmeal) will be included. The major producers and consumers.</p> <p>Vegetable oils and oilmeals are extracted from the oilseed. The importance of vegetable oils and animal fats will be highlighted, primarily in the food industry in Europe and worldwide. But in the past 15 years there have also been rapidly rising global requirements of oils &amp; fats for non-food purposes, primarily as a feedstock for biodiesel but also in the chemical industry.</p> <p>Importance of oilmeals as an animal feed for the production of livestock and aquaculture</p> <p>Oilseed area, yields per hectare as well as production of oilseeds. Analysis of the major oilseeds worldwide. The focus will be on soybeans, rapeseed, sunflowerseed, groundnuts and cottonseed.</p> <p>Regional differences in productivity. The winners and losers in global agricultural production.</p> <p>3) Forecasts: Future Global Demand &amp; Production of Vegetable Oils</p> <p>Big challenges in the years ahead: Lack of arable land for the production of oilseeds, grains and other crops. Competition with livestock. Lack of water. What are possible solutions? Need for better education &amp; management, more mechanization, better seed varieties and better inputs to raise yields.</p> <p>The importance of prices and changes in relative prices to solve market imbalances (shortage situations as well as surplus situations). How does it work? Time lags.</p> <p>Rapidly rising population, primarily the number of people considered "middle class" in the years ahead.</p> <p>Higher disposable income will trigger changing diets in favour of vegetable oils and livestock products.</p> <p>Urbanization. Today, food consumption per caput is partly still very low in many developing countries, primarily in Africa, some regions of Asia and in Central America. What changes are to be expected?</p> <p>The myth and the realities of palm oil in the world of today and tomorrow.</p> <p>Labour issues curb production growth: Some examples: 1) Shortage of labour in oil palm plantations in Malaysia. 2) Structural reforms overdue for the agriculture in India, China and other countries to become more productive and successful, thus improving the standard of living of smallholders.</p> |
| <b>Literature</b>                                                        | Lecture material                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

| Course L1767: Thermal Biomass Utilization |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
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| <b>Typ</b>                                | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Hrs/wk</b>                             | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>CP</b>                                 | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Workload in Hours</b>                  | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Lecturer</b>                           | Prof. Martin Kaltschmitt                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Language</b>                           | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Cycle</b>                              | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Content</b>                            | <p>Goal of this course is it to discuss the physical, chemical, and biological as well as the technical, economic, and environmental basics of all options to provide energy from biomass from a German and international point of view. Additionally different system approaches to use biomass for energy, aspects to integrate bioenergy within the energy system, technical and economic development potentials, and the current and expected future use within the energy system are presented.</p> <p>The course is structured as follows:</p> <ul style="list-style-type: none"> <li>• Biomass as an energy carrier within the energy system; use of biomass in Germany and world-wide, overview on the content of the course</li> <li>• Photosynthesis, composition of organic matter, plant production, energy crops, residues, organic waste</li> <li>• Biomass provision chains for woody and herbaceous biomass, harvesting and provision, transport, storage, drying</li> <li>• Thermo-chemical conversion of solid biofuels <ul style="list-style-type: none"> <li>◦ Basics of thermo-chemical conversion</li> <li>◦ Direct thermo-chemical conversion through combustion: combustion technologies for small and large scale units, electricity generation technologies, flue gas treatment technologies, ashes and their use</li> <li>◦ Gasification: Gasification technologies, producer gas cleaning technologies, options to use the cleaned producer gas for the provision of heat, electricity and/or fuels</li> <li>◦ Fast and slow pyrolysis: Technologies for the provision of bio-oil and/or for the provision of charcoal, oil cleaning technologies, options to use the pyrolysis oil and charcoal as an energy carrier as well as a raw material</li> </ul> </li> <li>• Physical-chemical conversion of biomass containing oils and/or fats: Basics, oil seeds and oil fruits, vegetable oil production, production of a biofuel with standardized characteristics (trans-esterification, hydrogenation, co-processing in existing refineries), options to use this fuel, options to use the residues (i.e. meal, glycerine)</li> <li>• Bio-chemical conversion of biomass <ul style="list-style-type: none"> <li>◦ Basics of bio-chemical conversion</li> <li>◦ Biogas: Process technologies for plants using agricultural feedstock, sewage sludge (sewage gas), organic waste fraction (landfill gas), technologies for the provision of bio methane, use of the digested slurry</li> <li>◦ Ethanol production: Process technologies for feedstock containing sugar, starch or celluloses, use of ethanol as a fuel, use of the stillage</li> </ul> </li> </ul> |
| <b>Literature</b>                         | <b>Kaltschmitt, M.; Hartmann, H. (Hrsg.): Energie aus Biomasse; Springer, Berlin, Heidelberg, 2009, 2. Auflage</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

| Course L2386: Thermal Biomass Utilization |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|-------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                | Practical Course                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Hrs/wk</b>                             | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>CP</b>                                 | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Workload in Hours</b>                  | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Lecturer</b>                           | Prof. Martin Kaltschmitt, Dr. Marvin Scherzinger                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Language</b>                           | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Cycle</b>                              | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Content</b>                            | <p>The experiments of the practical lab course illustrate the different aspects of heat generation from biogenic solid fuels. First, different biomasses (e.g. wood, straw or agricultural residues) will be investigated; the focus will be on the calorific value of the biomass. Furthermore, the used biomass will be pelletized, the pellet properties analysed and a combustion test carried out on a pellet combustion system. The gaseous and solid pollutant emissions, especially the particulate matter emissions, are measured and the composition of the particulate matter is investigated in a further experiment. Another focus of the practical course is the consideration of options for the reduction of particulate matter emissions from biomass combustion. In the practical course, a method for particulate matter reduction will be developed and tested. All experiments will be evaluated and the results presented.</p> <p>Within the practical lab course the students discuss different technical-scientific tasks, both subject-specifically and interdisciplinary. They discuss various approaches to solving the problem and advise on the theoretical or practical implementation.</p> |
| <b>Literature</b>                         | <p>- Kaltschmitt, Martin; Hartmann, Hans; Hofbauer, Hermann: Energie aus Biomasse: Grundlagen, Techniken und Verfahren. 3. Auflage. Berlin Heidelberg: Springer Science &amp; Business Media, 2016. -ISBN 978-3-662-47437-2</p> <p>- Versuchsskript</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

| Module M1303: Energy Projects - Development and Assessment |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |        |    |
|------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|----|
| Courses                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |        |    |
| Title                                                      | Type                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Hrs/wk | CP |
| Aspects of Sustainability Management (L0007)               | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1      | 1  |
| Development of Energy Projects (L0003)                     | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 2      | 2  |
| Renewable Energy Projects in Emerged Markets (L0014)       | Project Seminar                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2      | 2  |
| Economic Aspects of Energy Projects (L0005)                | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1      | 1  |
| <b>Module Responsible</b>                                  | Prof. Martin Kaltschmitt                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |    |
| <b>Admission Requirements</b>                              | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |        |    |
| <b>Recommended Previous Knowledge</b>                      | Environmental Assessment                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |    |
| <b>Educational Objectives</b>                              | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |        |    |
| <b>Professional Competence</b>                             | <p><i>Knowledge</i> By ending this module, students can describe the planning and development of projects using renewable energy sources. Furthermore they are able to explain the special emphasis on the economic and legal aspects in this context.</p> <p>The learning content of the different topics of the module are use-oriented; thus students can apply them i.a. in professional fields of consultation or supervision of energy projects.</p> <p><i>Skills</i> By ending the module the students can apply the learned theoretical foundations of the development of renewable energy projects to exemplary energy projects and can explain technically and conceptually the resulting correlations with respect to legal and economic requirements.</p> <p>As a basis for the design of renewable energy systems they can calculate the demand for thermal and/or electrical energy at operating and regional level. Regarding to this calculation they can choose and dimension possible energy systems.</p> <p>To assess sustainability aspects of renewable energy projects, the students can choose and discuss the right methodology according to the particular task.</p> <p>Through active discussions of various topics within the seminars and exercises of the module, students improve their understanding and the application of the theoretical background and are thus able to transfer what they have learned in practice.</p> |        |    |
| <b>Personal Competence</b>                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |        |    |
| <i>Social Competence</i>                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |        |    |
| <i>Autonomy</i>                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |        |    |
|                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |        |    |
| <b>Workload in Hours</b>                                   | Independent Study Time 96, Study Time in Lecture 84                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |        |    |
| <b>Credit points</b>                                       | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |        |    |
| <b>Course achievement</b>                                  | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |        |    |
| <b>Examination</b>                                         | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |        |    |
| <b>Examination duration and scale</b>                      | 150 minutes written exam + Written essay from project seminar                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |        |    |
| <b>Assignment for the Following Curricula</b>              | Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory<br>Renewable Energies: Core Qualification: Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |        |    |

| Course L0007: Aspects of Sustainability Management |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                         | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Hrs/wk</b>                                      | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>CP</b>                                          | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Workload in Hours</b>                           | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Lecturer</b>                                    | Charlotte Weinspach                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Language</b>                                    | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Cycle</b>                                       | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Content</b>                                     | <p>The lecture "Sustainability Management" gives an insight into the different aspects and dimensions of sustainability. First, essential terms and definitions, significant developments of the last years, and legal framework conditions are explained. The various aspects of sustainability are then presented and discussed in detail. The lecture mainly focuses on concepts for the implementation of the topic sustainability in companies:</p> <ul style="list-style-type: none"> <li>• What is "sustainability"?</li> <li>• Why is this concept an important topic for companies?</li> <li>• What opportunities and business risks are addressed or are associated with it?</li> <li>• How can the often mentioned three pillars of sustainability - economy, ecology, and social- be meaningfully integrated into corporate management despite their sometimes contradictory tendencies, and how a corresponding compromise can be found?</li> <li>• What concepts or frameworks exist for the implementation of sustainability management in companies?</li> <li>• Which sustainability labels exist for products or companies? What do they have in common, and where do they differ?</li> </ul> <p>Furthermore, the lecture is intended to provide insights into the concrete implementation of sustainability aspects into business practice. External lecturers from companies will be invited to report on how sustainability is integrated into their daily processes.</p> <p>In the course of an independently carried out group work, the students will analyze and discuss the implementation of sustainability aspects based on short case studies. By studying and comparing best practice examples, the students will learn about corporate decisions' effects and implications. It should become clear which risks or opportunities are associated if sustainability aspects are taken into account in management decisions.</p> |
| <b>Literature</b>                                  | <p>Die folgenden Bücher bieten einen Überblick:</p> <p>Engelfried, J. (2011) Nachhaltiges Umweltmanagement. München: Oldenbourg Verlag. 2. Auflage</p> <p>Corsten H., Roth S. (Hrsg.) (2011) Nachhaltigkeit - Unternehmerisches Handeln in globaler Verantwortung. Wiesbaden: Gabler Verlag.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

| Course L0003: Development of Energy Projects |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|----------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                   | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Hrs/wk</b>                                | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>CP</b>                                    | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Workload in Hours</b>                     | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Lecturer</b>                              | Prof. Martin Kaltschmitt                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Language</b>                              | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Cycle</b>                                 | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Content</b>                               | <ul style="list-style-type: none"> <li>• Development of renewable energy projects from the analysis of the local situation to the final energy project: what steps have to be completed in order to implement a successful regenerative energy project and what factors must be considered</li> <li>• Survey of energy demand; methods to collect the demand for thermal and/or electrical energy at operational and regional level until the point of a development of an energy master plan</li> <li>• Technology of renewable energy: how to combine the various options for using renewable energy with different supply situation in the most reasonable way? How can under certain conditions ideal combinations look like?</li> <li>• Feasibility study, requirements and content of a feasibility study</li> <li>• Legal framework for plant construction; representation of authorization rights, including the entire formal procedure for the different approval procedures in the context of the BImSch legislation; further legal requirements (including laws pertaining to construction, water and waterways, noise, etc.</li> <li>• Company structures; which company structure is the most appropriate for the various applications? What are the pros and cons?</li> <li>• Risk management: how the risks of renewable energy projects can be best determined? How the minimizing of risk can be ensured?</li> <li>• Insurance: which kinds of insurance exist? Why do you need insurance? What requirements must be met in order to obtain certain types of insurance for certain renewable energy projects for the construction and operational phase?</li> <li>• Acceptance: how the acceptance of an application for the use of renewable energy can be assessed and improved? How the acceptance can be measured?</li> <li>• Organization of realization of a project: how the construction phase of a renewable energy system is organized after the end of the planning period?</li> <li>• Acceptance: Which are the acceptance steps until the regular continuous operation (VOB acceptance, safety acceptance, approval by authority)</li> <li>• Examples: good and less good examples of project development</li> </ul> |
| <b>Literature</b>                            | <ul style="list-style-type: none"> <li>• Script zur Vorlesung mit Literaturhinweisen</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

| Course L0014: Renewable Energy Projects in Emerged Markets |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
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| <b>Typ</b>                                                 | Project Seminar                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Hrs/wk</b>                                              | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>CP</b>                                                  | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Workload in Hours</b>                                   | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Lecturer</b>                                            | Prof. Andreas Wiese                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Language</b>                                            | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Cycle</b>                                               | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Content</b>                                             | <ol style="list-style-type: none"> <li>1. Introduction <ul style="list-style-type: none"> <li>◦ Development of renewable energies worldwide <ul style="list-style-type: none"> <li>▪ History</li> <li>▪ Future markets</li> </ul> </li> <li>◦ Special challenges in new markets - Overview</li> </ul> </li> <li>2. Sample project wind farm Korea <ul style="list-style-type: none"> <li>◦ Survey</li> <li>◦ Technical Description</li> <li>◦ Project phases and characteristics</li> </ul> </li> <li>3. Funding and financing instruments for EE projects in new markets <ul style="list-style-type: none"> <li>◦ Overview funding opportunitie</li> <li>◦ Overview countries with feed-in laws</li> <li>◦ Major funding programs</li> </ul> </li> <li>4. CDM projects - why, how , examples <ul style="list-style-type: none"> <li>◦ Overview CDM process</li> <li>◦ Examples</li> <li>◦ Exercise CDM</li> </ul> </li> <li>5. Rural electrification and hybrid systems - an important future market for EE <ul style="list-style-type: none"> <li>◦ Rural Electrification - Introduction</li> <li>◦ Types of Elektrizifizierungsprojekten</li> <li>◦ The role of the EEInterpretation of hybrid systems</li> <li>◦ Project example: hybrid system Galapagos Islands</li> </ul> </li> <li>6. Tendering process for EE projects - examples <ul style="list-style-type: none"> <li>◦ South Africa</li> <li>◦ Brazil</li> </ul> </li> <li>7. Selected projects from the perspective of a development bank - Wesley Urena Vargas, KfW Development Bank <ul style="list-style-type: none"> <li>◦ Geothermal</li> <li>◦ Wind or CSP</li> </ul> </li> </ol> <p>Within the seminar, the various topics are actively discussed and applied to various cases of application.</p> |
| <b>Literature</b>                                          | Folien der Vorlesung                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |



| Course L0005: Economic Aspects of Energy Projects |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|---------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                        | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Hrs/wk</b>                                     | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>CP</b>                                         | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Workload in Hours</b>                          | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Lecturer</b>                                   | Prof. Andreas Wiese                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Language</b>                                   | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Cycle</b>                                      | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Content</b>                                    | <ul style="list-style-type: none"> <li>• Introduction: definitions; importance of cost and profitability statements for projects in the "Renewable Energies"; prices and costs; efficiency of energy systems versus profitability of individual project</li> <li>• Cost estimates and cost calculations <ul style="list-style-type: none"> <li>◦ Definitions</li> <li>◦ Cost calculation</li> <li>◦ Cost estimation</li> <li>◦ Calculation of costs for the provision of work and power</li> <li>◦ Cost summaries for renewable energy technologies</li> <li>◦ Energy Storage: cost overviews; impact on the cost of renewable energy projects</li> </ul> </li> <li>• Efficiency calculation <ul style="list-style-type: none"> <li>◦ Definitions</li> <li>◦ Methods: static methods, dynamic methods (eg. LCOE (levelised cost of electricity))</li> <li>◦ Economic versus national economic approach</li> <li>◦ Power and work in cost accounting</li> <li>◦ Energy storage and its influence on the efficiency calculation</li> </ul> </li> <li>• The due diligence process as an attendant of economic analysis</li> <li>• Consideration of uncertainty in projects for renewable energy <ul style="list-style-type: none"> <li>◦ Definitions</li> <li>◦ Technical uncertainty</li> <li>◦ Cost uncertainties</li> <li>◦ Other uncertainties</li> </ul> </li> <li>• Project financing <ul style="list-style-type: none"> <li>◦ Definitions</li> <li>◦ Project -versus corporate finance</li> <li>◦ Funding models</li> <li>◦ Equity ratio , DSCR</li> <li>◦ Treatment of risks in project financing</li> <li>◦ Funding opportunities for renewable energy projects</li> <li>◦ Possible funding approaches</li> <li>◦ Legal requirements in Germany (EEG )</li> <li>◦ Emissions trading and carbon credits</li> </ul> </li> </ul> |
| <b>Literature</b>                                 | Script der Vorlesung                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

| Module M1309: Dimensioning and Assessment of Renewable Energy Systems |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                 |        |    |
|-----------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|--------|----|
| Courses                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                 |        |    |
| Title                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Typ                             | Hrs/wk | CP |
| Environmental Technology and Energy Economics (L0137)                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Project-/problem-based Learning | 2      | 2  |
| Electricity Generation from Renewable Sources of Energy (L0046)       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Seminar                         | 2      | 2  |
| Heat Provision from Renewable Sources of Energy (L0045)               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Seminar                         | 2      | 2  |
| Module Responsible                                                    | Prof. Martin Kaltschmitt                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                 |        |    |
| Admission Requirements                                                | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                 |        |    |
| Recommended Previous Knowledge                                        | none                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                 |        |    |
| Educational Objectives                                                | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                 |        |    |
| <b>Professional Competence</b><br><i>Knowledge</i>                    | The students can describe current issue and problems in the field of renewable energies. Furthermore, they can explain aspects in relation to the provision of heat or electricity through different renewable technologies, and explain and assess them in a technical, economical and environmental way.                                                                                                                                                                                                                                                                                          |                                 |        |    |
| <i>Skills</i>                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                 |        |    |
|                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                 |        |    |
|                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                 |        |    |
| <b>Personal Competence</b><br><i>Social Competence</i>                | Students can <ul style="list-style-type: none"><li>• respectfully work together as a team with around 2-3 members,</li><li>• participate in subject-specific and interdisciplinary discussions in the area of dimensioning and analysis of potentials of heat and electricity supply using renewable energie, and can develop cooperated solutions,</li><li>• defend their own work results in front of fellow students and</li><li>• assess the performance of fellow students in comparison to their own performance. Furthermore, they can accept professional constructive criticism.</li></ul> |                                 |        |    |
| <i>Autonomy</i>                                                       | Students can independently tap knowledge regarding to the given task. They are capable, in consultation with supervisors, to assess their learning level and define further steps on this basis. Furthermore, they can define targets for new application-or research-oriented duties in accordance with the potential social, economic and cultural impact.                                                                                                                                                                                                                                        |                                 |        |    |
| Workload in Hours                                                     | Independent Study Time 96, Study Time in Lecture 84                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                 |        |    |
| Credit points                                                         | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                 |        |    |
| Course achievement                                                    | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                 |        |    |
| Examination                                                           | Written elaboration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                 |        |    |
| Examination duration and scale                                        | per course: 20 minutes presentation + written report                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                 |        |    |
| Assignment for the Following Curricula                                | Energy Systems: Specialisation Energy Systems: Compulsory<br>Renewable Energies: Core Qualification: Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                 |        |    |

| Course L0137: Environmental Technology and Energy Economics |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
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| Typ                                                         | Project-/problem-based Learning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Hrs/wk                                                      | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| CP                                                          | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Workload in Hours                                           | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Lecturer                                                    | Prof. Martin Kaltschmitt, Prof. Arne Speerforck                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Language                                                    | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Cycle                                                       | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Content                                                     | <ul style="list-style-type: none"><li>• Preliminary discussion with the rules of the lecture</li><li>• Issue of topics from the field of renewable energy technology in the form of a tender of engineering services to a group of students (depending on the number of participating students)</li><li>• "Procurement" deal with aspects of the design, costing and environmental, economic and technical evaluation of various energy generation concepts (eg onshore wind power generation, commercial-scale photovoltaic power generation, biogas production, geothermal power and heat generation) under very special circumstances</li><li>• Submission of a written solution of the task and distribution to the participants by the student / group of students</li><li>• Presentation of the edited theme (20 min) with PPT presentation and subsequent discussion (20 minutes)</li><li>• Attendance is mandatory for all seminars</li></ul> |
| Literature                                                  | Eigenständiges Literaturstudium in der Bibliothek und aus anderen Quellen.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

| Course L0046: Electricity Generation from Renewable Sources of Energy |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-----------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                            | Seminar                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Hrs/wk</b>                                                         | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>CP</b>                                                             | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Workload in Hours</b>                                              | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Lecturer</b>                                                       | Prof. Martin Kaltschmitt, Prof. Arne Speerforck                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Language</b>                                                       | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Cycle</b>                                                          | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Content</b>                                                        | <ul style="list-style-type: none"> <li>• Preliminary discussion with the seminar rules</li> <li>• Distribution of the topics related to the subject of the seminar to individual students / groups of students (depending on the number of participating students)</li> <li>• Delivery of a five-page summary of the seminar topic and distribution to the participants by the student / group of students</li> <li>• Presentation of the processed topic (30 min) with PPT presentation and subsequent discussion (20 minutes)</li> <li>• Attendance is mandatory for all seminars</li> </ul> |
| <b>Literature</b>                                                     | <ul style="list-style-type: none"> <li>• Eigenständiges Literaturstudium in der Bibliothek und aus anderen Quellen.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

| Course L0045: Heat Provision from Renewable Sources of Energy |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|---------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                    | Seminar                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Hrs/wk</b>                                                 | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>CP</b>                                                     | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Workload in Hours</b>                                      | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Lecturer</b>                                               | Prof. Martin Kaltschmitt, Prof. Arne Speerforck                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Language</b>                                               | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Cycle</b>                                                  | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Content</b>                                                | <ul style="list-style-type: none"> <li>• Preliminary discussion with the seminar rules</li> <li>• Distribution of the topics related to the subject of the seminar to individual students / groups of students (depending on the number of participating students)</li> <li>• Delivery of a five-page summary of the seminar topic and distribution to the participants by the student / group of students</li> <li>• Presentation of the processed topic (30 min) with PPT presentation and subsequent discussion (20 minutes)</li> <li>• Attendance is mandatory for all seminars</li> </ul> |
| <b>Literature</b>                                             | Eigenständiges Literaturstudium in der Bibliothek und aus anderen Quellen.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

| Module M1250: Electrical Power Systems II: Operation and Information Systems of Electrical Power Grids |                                                                                                                                                                                                                                                                                                                                                                                                          |  |        |    |
|--------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--------|----|
| Courses                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                          |  |        |    |
| Title                                                                                                  | Typ                                                                                                                                                                                                                                                                                                                                                                                                      |  | Hrs/wk | CP |
| Electrical Power Systems II: Operation and Information Systems of Electrical Power Grids (L1696)       | Lecture                                                                                                                                                                                                                                                                                                                                                                                                  |  | 3      | 4  |
| Electrical Power Systems II: Operation and Information Systems of Electrical Power Grids (L1697)       | Recitation Section (large)                                                                                                                                                                                                                                                                                                                                                                               |  | 2      | 2  |
| <b>Module Responsible</b>                                                                              | Prof. Christian Becker                                                                                                                                                                                                                                                                                                                                                                                   |  |        |    |
| <b>Admission Requirements</b>                                                                          | None                                                                                                                                                                                                                                                                                                                                                                                                     |  |        |    |
| <b>Recommended Previous Knowledge</b>                                                                  | Fundamentals of Electrical Engineering,<br>Electrical Power Systems I,<br>Mathematics I, II, III                                                                                                                                                                                                                                                                                                         |  |        |    |
| <b>Educational Objectives</b>                                                                          | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                     |  |        |    |
| <b>Professional Competence</b><br><i>Knowledge</i>                                                     | Students are able to explain in detail and critically evaluate technologies and information systems for operational management of conventional and modern electric power systems as well as methods and algorithms for steady-state network calculation, failure calculation, power system operation and optimization. They are additionally able to apply these methods to real electric power systems. |  |        |    |
| <i>Skills</i>                                                                                          | With completion of this module the students are able to apply the acquired skills for planning and analysis of real electric power systems and to critically evaluate the results.                                                                                                                                                                                                                       |  |        |    |
| <b>Personal Competence</b><br><i>Social Competence</i>                                                 | The students can participate in specialized and interdisciplinary discussions, advance ideas and represent their own work results in front of others.                                                                                                                                                                                                                                                    |  |        |    |
| <i>Autonomy</i>                                                                                        | Students can independently tap knowledge of the emphasis of the lectures and apply it within further research activities.                                                                                                                                                                                                                                                                                |  |        |    |
| <b>Workload in Hours</b>                                                                               | Independent Study Time 110, Study Time in Lecture 70                                                                                                                                                                                                                                                                                                                                                     |  |        |    |
| <b>Credit points</b>                                                                                   | 6                                                                                                                                                                                                                                                                                                                                                                                                        |  |        |    |
| <b>Course achievement</b>                                                                              | None                                                                                                                                                                                                                                                                                                                                                                                                     |  |        |    |
| <b>Examination</b>                                                                                     | Oral exam                                                                                                                                                                                                                                                                                                                                                                                                |  |        |    |
| <b>Examination duration and scale</b>                                                                  | 45 min                                                                                                                                                                                                                                                                                                                                                                                                   |  |        |    |
| <b>Assignment for the Following Curricula</b>                                                          | Electrical Engineering and Information Technology: Core Qualification: Compulsory<br>Electrical Engineering: Core Qualification: Compulsory<br>Energy Systems: Specialisation Energy Systems: Elective Compulsory<br>Computer Science in Engineering: Specialisation II. Engineering Science: Elective Compulsory<br>Renewable Energies: Core Qualification: Compulsory                                  |  |        |    |

| Course L1696: Electrical Power Systems II: Operation and Information Systems of Electrical Power Grids |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|--------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                                                             | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Hrs/wk</b>                                                                                          | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>CP</b>                                                                                              | 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Workload in Hours</b>                                                                               | Independent Study Time 78, Study Time in Lecture 42                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Lecturer</b>                                                                                        | Prof. Christian Becker                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Language</b>                                                                                        | EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Cycle</b>                                                                                           | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Content</b>                                                                                         | <ul style="list-style-type: none"> <li>• steady-state modelling of electric power systems               <ul style="list-style-type: none"> <li>◦ conventional components</li> <li>◦ Flexible AC Transmission Systems (FACTS) and HVDC</li> <li>◦ grid modelling</li> </ul> </li> <li>• grid operation               <ul style="list-style-type: none"> <li>◦ electric power supply processes</li> <li>◦ grid and power system management</li> <li>◦ grid provision</li> </ul> </li> <li>• grid control systems               <ul style="list-style-type: none"> <li>◦ information and communication systems for power system management</li> <li>◦ IT architectures of bay-, substation and network control level</li> <li>◦ IT integration (energy market / supply shortfall management / asset management)</li> <li>◦ future trends of process control technology</li> <li>◦ smart grids</li> </ul> </li> <li>• functions and steady-state computations for power system operation and planning               <ul style="list-style-type: none"> <li>◦ load-flow calculations</li> <li>◦ sensitivity analysis and power flow control</li> <li>◦ power system optimization</li> <li>◦ short-circuit calculation</li> <li>◦ asymmetric failure calculation                   <ul style="list-style-type: none"> <li>▪ symmetric components</li> <li>▪ calculation of asymmetric failures</li> </ul> </li> <li>◦ state estimation</li> </ul> </li> </ul> |
| <b>Literature</b>                                                                                      | E. Handschin: Elektrische Energieübertragungssysteme, Hüthig Verlag<br>B. R. Oswald: Berechnung von Drehstromnetzen, Springer-Vieweg Verlag<br>V. Crastan: Elektrische Energieversorgung Bd. 1 & 3, Springer Verlag<br>E.-G. Tietze: Netzleittechnik Bd. 1 & 2, VDE-Verlag                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

| Course L1697: Electrical Power Systems II: Operation and Information Systems of Electrical Power Grids |                                                     |
|--------------------------------------------------------------------------------------------------------|-----------------------------------------------------|
| <b>Typ</b>                                                                                             | Recitation Section (large)                          |
| <b>Hrs/wk</b>                                                                                          | 2                                                   |
| <b>CP</b>                                                                                              | 2                                                   |
| <b>Workload in Hours</b>                                                                               | Independent Study Time 32, Study Time in Lecture 28 |
| <b>Lecturer</b>                                                                                        | Prof. Christian Becker                              |
| <b>Language</b>                                                                                        | EN                                                  |
| <b>Cycle</b>                                                                                           | WiSe                                                |
| <b>Content</b>                                                                                         | See interlocking course                             |
| <b>Literature</b>                                                                                      | See interlocking course                             |

| Module M2136: Fluid Mechanics and Ocean Energy |                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |              |                  |                    |
|------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|------------------|--------------------|
| Courses                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |              |                  |                    |
| Title                                          | Typ                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |              | Hrs/wk           | CP                 |
| Energy from the Ocean (L0002)                  | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |              | 2                | 2                  |
| Fluid Mechanics II (L0001)                     | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |              | 2                | 4                  |
| <b>Module Responsible</b>                      | Prof. Michael Schlüter                                                                                                                                                                                                                                                                                                                                                                                                                                                     |              |                  |                    |
| <b>Admission Requirements</b>                  | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |              |                  |                    |
| <b>Recommended Previous Knowledge</b>          | Technische Thermodynamik I-II<br>Wärme- und Stoffübertragung                                                                                                                                                                                                                                                                                                                                                                                                               |              |                  |                    |
| <b>Educational Objectives</b>                  | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                       |              |                  |                    |
| <b>Professional Competence</b>                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |              |                  |                    |
| <i>Knowledge</i>                               | The students are able to describe different applications of fluid mechanics for the field of Renewable Energies. They are able to use the fundamentals of fluid mechanics for calculations of certain engineering problems in the field of ocean energy. The students are able to estimate if a problem can be solved with an analytical solution and what kind of alternative possibilities are available (e.g. self-similarity, empirical solutions, numerical methods). |              |                  |                    |
| <i>Skills</i>                                  | Students are able to use the governing equations of Fluid Dynamics for the design of technical processes. Especially they are able to formulate momentum and mass balances to optimize the hydrodynamics of technical processes. They are able to transform a verbal formulated message into an abstract formal procedure.                                                                                                                                                 |              |                  |                    |
| <b>Personal Competence</b>                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |              |                  |                    |
| <i>Social Competence</i>                       | The students are able to discuss a given problem in small groups and to develop an approach. They are able to solve a problem within a team, to prepare a poster with the results and to present the poster.                                                                                                                                                                                                                                                               |              |                  |                    |
| <i>Autonomy</i>                                | Students are able to define independently tasks for problems related to fluid mechanics. They are able to work out the knowledge that is necessary to solve the problem by themselves on the basis of the existing knowledge from the lecture.                                                                                                                                                                                                                             |              |                  |                    |
| <b>Workload in Hours</b>                       | Independent Study Time 124, Study Time in Lecture 56                                                                                                                                                                                                                                                                                                                                                                                                                       |              |                  |                    |
| <b>Credit points</b>                           | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |              |                  |                    |
| <b>Course achievement</b>                      | <b>Compulsory</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <b>Bonus</b> | <b>Form</b>      | <b>Description</b> |
|                                                | No                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 10 %         | Group discussion |                    |
| <b>Examination</b>                             | Subject theoretical and practical work                                                                                                                                                                                                                                                                                                                                                                                                                                     |              |                  |                    |
| <b>Examination duration and scale</b>          | Poster discussion                                                                                                                                                                                                                                                                                                                                                                                                                                                          |              |                  |                    |
| <b>Assignment for the Following Curricula</b>  | Energy Systems: Core Qualification: Elective Compulsory<br>International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory<br>Renewable Energies: Core Qualification: Compulsory<br>Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory                                                                                                                                                              |              |                  |                    |

| Course L0002: Energy from the Ocean |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|-------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                          | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Hrs/wk</b>                       | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>CP</b>                           | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Workload in Hours</b>            | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Lecturer</b>                     | Prof. Moustafa Abdel-Maksoud, Dr. Robinson Peric                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Language</b>                     | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Cycle</b>                        | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Content</b>                      | <ol style="list-style-type: none"> <li>1. Introduction to ocean energy conversion</li> <li>2. Wave properties <ul style="list-style-type: none"> <li>◦ Linear wave theory</li> <li>◦ Nonlinear wave theory</li> <li>◦ Irregular waves</li> <li>◦ Wave energy</li> <li>◦ Refraction, reflection and diffraction of waves</li> </ul> </li> <li>3. Wave energy converters <ul style="list-style-type: none"> <li>◦ Overview of the different technologies</li> <li>◦ Methods for design and calculation</li> </ul> </li> <li>4. Ocean current turbine</li> </ol>                                                                                                |
| <b>Literature</b>                   | <ul style="list-style-type: none"> <li>• Cruz, J., Ocean wave energy, Springer Series in Green Energy and Technology, UK, 2008.</li> <li>• Brooke, J., Wave energy conversion, Elsevier, 2003.</li> <li>• McCormick, M.E., Ocean wave energy conversion, Courier Dover Publications, USA, 2013.</li> <li>• Falnes, J., Ocean waves and oscillating systems, Cambridge University Press, UK, 2002.</li> <li>• Charlier, R. H., Charles, W. F., Ocean energy. Tide and tidal Power. Berlin, Heidelberg, 2009.</li> <li>• Clauss, G. F., Lehmann, E., Østergaard, C., Offshore Structures. Volume 1, Conceptual Design. Springer-Verlag, Berlin 1992</li> </ul> |

| Course L0001: Fluid Mechanics II |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                       | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Hrs/wk</b>                    | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>CP</b>                        | 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Workload in Hours</b>         | Independent Study Time 92, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Lecturer</b>                  | Prof. Michael Schlüter                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Language</b>                  | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Cycle</b>                     | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Content</b>                   | <ul style="list-style-type: none"> <li>• Differential equations for momentum-, heat and mass transfer</li> <li>• Examples for simplifications of the Navier-Stokes Equations</li> <li>• Unsteady momentum transfer</li> <li>• Free shear layer, turbulence and free jets</li> <li>• Flow around particles - Solids Process Engineering</li> <li>• Coupling of momentum and heat transfer - Thermal Process Engineering</li> <li>• Rheology - Bioprocess Engineering</li> <li>• Coupling of momentum- and mass transfer – Reactive mixing, Chemical Process Engineering</li> <li>• Flow through porous structures - heterogeneous catalysis</li> <li>• Pumps and turbines - Energy- and Environmental Process Engineering</li> <li>• Wind- and Wave-Turbines - Renewable Energy</li> <li>• Introduction into Computational Fluid Dynamics</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Literature</b>                | <ol style="list-style-type: none"> <li>1. Brauer, H.: Grundlagen der Einphasen- und Mehrphasenströmungen. Verlag Sauerländer, Aarau, Frankfurt (M), 1971.</li> <li>2. Brauer, H.; Mewes, D.: Stoffaustausch einschließlich chemischer Reaktion. Frankfurt: Sauerländer 1972.</li> <li>3. Crowe, C. T.: Engineering fluid mechanics. Wiley, New York, 2009.</li> <li>4. Durst, F.: Strömungsmechanik: Einführung in die Theorie der Strömungen von Fluiden. Springer-Verlag, Berlin, Heidelberg, 2006.</li> <li>5. Fox, R.W.; et al.: Introduction to Fluid Mechanics. J. Wiley &amp; Sons, 1994.</li> <li>6. Herwig, H.: Strömungsmechanik: Eine Einführung in die Physik und die mathematische Modellierung von Strömungen. Springer Verlag, Berlin, Heidelberg, New York, 2006.</li> <li>7. Herwig, H.: Strömungsmechanik: Einführung in die Physik von technischen Strömungen: Vieweg+Teubner Verlag / GWV Fachverlage GmbH, Wiesbaden, 2008.</li> <li>8. Kuhlmann, H.C.: Strömungsmechanik. München, Pearson Studium, 2007</li> <li>9. Oertl, H.: Strömungsmechanik: Grundlagen, Grundgleichungen, Lösungsmethoden, Softwarebeispiele. Vieweg+ Teubner / GWV Fachverlage GmbH, Wiesbaden, 2009.</li> <li>10. Schade, H.; Kunz, E.: Strömungslehre. Verlag de Gruyter, Berlin, New York, 2007.</li> <li>11. Truckenbrodt, E.: Fluidmechanik 1: Grundlagen und elementare Strömungsvorgänge dichtebeständiger Fluide. Springer-Verlag, Berlin, Heidelberg, 2008.</li> <li>12. Schlichting, H. : Grenzschicht-Theorie. Springer-Verlag, Berlin, 2006.</li> <li>13. van Dyke, M.: An Album of Fluid Motion. The Parabolic Press, Stanford California, 1982.</li> </ol> |

| Module M0512: Use of Solar Energy                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |                     |                               |
|--------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|---------------------|-------------------------------|
| Courses                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |                     |                               |
| Title                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Typ                        | Hrs/wk              | CP                            |
| Energy Meteorology (L0016)                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Lecture                    | 1                   | 1                             |
| Energy Meteorology (L0017)                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Recitation Section (small) | 1                   | 1                             |
| Collector Technology (L0018)                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Lecture                    | 2                   | 2                             |
| Solar Power Generation (L0015)                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Lecture                    | 2                   | 2                             |
| Module Responsible                                     | Prof. Martin Kaltschmitt                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                            |                     |                               |
| Admission Requirements                                 | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                            |                     |                               |
| Recommended Previous Knowledge                         | none                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                            |                     |                               |
| Educational Objectives                                 | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                            |                     |                               |
| <b>Professional Competence</b><br><i>Knowledge</i>     | With the completion of this module, students will be able to deal with technical foundations and current issues and problems in the field of solar energy and explain and evaluate these critically in consideration of the prior curriculum and current subject specific issues. In particular they can professionally describe the processes within a solar cell and explain the specific features of application of solar modules. Furthermore, they can provide an overview of the collector technology in solar thermal systems.            |                            |                     |                               |
| <i>Skills</i>                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |                     |                               |
| <b>Personal Competence</b><br><i>Social Competence</i> | Students are able to discuss issues in the thematic fields in the renewable energy sector addressed within the module.                                                                                                                                                                                                                                                                                                                                                                                                                           |                            |                     |                               |
| <i>Autonomy</i>                                        | Students can independently exploit sources and acquire the particular knowledge about the subject area with respect to emphasis fo the lectures. Furthermore, with the assistance of lecturers, they can discrete use calculation methods for analysing and dimensioning solar energy systems. Based on this procedure they can concrete assess their specific learning level and can consequently define the further workflow.                                                                                                                  |                            |                     |                               |
| Workload in Hours                                      | Independent Study Time 96, Study Time in Lecture 84                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                            |                     |                               |
| Credit points                                          | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                            |                     |                               |
| Course achievement                                     | Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Bonus                      | Form                | Description                   |
|                                                        | Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 20 %                       | Written elaboration | Ausarbeitung Kollektortechnik |
| Examination                                            | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                            |                     |                               |
| Examination duration and scale                         | 180 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                            |                     |                               |
| Assignment for the Following Curricula                 | Energy Systems: Specialisation Energy Systems: Elective Compulsory<br>International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory<br>International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory<br>Renewable Energies: Core Qualification: Compulsory<br>Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory |                            |                     |                               |



| Course L0016: Energy Meteorology |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                       | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Hrs/wk</b>                    | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>CP</b>                        | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Workload in Hours</b>         | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Lecturer</b>                  | Dr. Volker Matthias, Dr. Beate Geyer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Language</b>                  | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Cycle</b>                     | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Content</b>                   | <ul style="list-style-type: none"> <li>• Introduction: radiation source Sun, Astronomical Foundations, Fundamentals of radiation</li> <li>• Structure of the atmosphere</li> <li>• Properties and laws of radiation <ul style="list-style-type: none"> <li>◦ Polarization</li> <li>◦ Radiation quantities</li> <li>◦ Planck's radiation law</li> <li>◦ Wien's displacement law</li> <li>◦ Stefan-Boltzmann law</li> <li>◦ Kirchhoff's law</li> <li>◦ Brightness temperature</li> <li>◦ Absorption, reflection, transmission</li> </ul> </li> <li>• Radiation balance, global radiation, energy balance</li> <li>• Atmospheric extinction</li> <li>• Mie and Rayleigh scattering</li> <li>• Radiative transfer</li> <li>• Optical effects in the atmosphere</li> <li>• Calculation of the sun and calculate radiation on inclined surfaces</li> </ul> |
| <b>Literature</b>                | <ul style="list-style-type: none"> <li>• Helmut Kraus: Die Atmosphäre der Erde</li> <li>• Hans Häckel: Meteorologie</li> <li>• Grant W. Petty: A First Course in Atmospheric Radiation</li> <li>• Martin Kaltschmitt, Wolfgang Streicher, Andreas Wiese: Renewable Energy</li> <li>• Alexander Löw, Volker Matthias: Skript Optik Strahlung Fernerkundung</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

| Course L0017: Energy Meteorology |                                                     |
|----------------------------------|-----------------------------------------------------|
| <b>Typ</b>                       | Recitation Section (small)                          |
| <b>Hrs/wk</b>                    | 1                                                   |
| <b>CP</b>                        | 1                                                   |
| <b>Workload in Hours</b>         | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>                  | Dr. Beate Geyer                                     |
| <b>Language</b>                  | DE                                                  |
| <b>Cycle</b>                     | SoSe                                                |
| <b>Content</b>                   | See interlocking course                             |
| <b>Literature</b>                | See interlocking course                             |

| Course L0018: Collector Technology |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                         | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Hrs/wk</b>                      | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>CP</b>                          | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Workload in Hours</b>           | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Lecturer</b>                    | Dr. Korbinian Kramer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Language</b>                    | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Cycle</b>                       | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Content</b>                     | <ul style="list-style-type: none"> <li>• Introduction: Energy demand and application of solar energy.</li> <li>• Heat transfer in the solar thermal energy: conduction, convection, radiation.</li> <li>• Collectors: Types, structure, efficiency, dimensioning, concentrated systems.</li> <li>• Energy storage: Requirements, types.</li> <li>• Passive solar energy: components and systems.</li> <li>• Solar thermal low temperature systems: collector variants, construction, calculation.</li> <li>• Solar thermal high temperature systems: Classification of solar power plants construction.</li> <li>• Solar air conditioning.</li> </ul>                                       |
| <b>Literature</b>                  | <ul style="list-style-type: none"> <li>• Vorlesungsskript.</li> <li>• Kaltschmitt, Streicher und Wiese (Hrsg.). Erneuerbare Energien: Systemtechnik, Wirtschaftlichkeit, Umweltaspekte, 5. Auflage, Springer, 2013.</li> <li>• Stieglitz und Heinzel .Thermische Solarenergie: Grundlagen, Technologie, Anwendungen. Springer, 2012.</li> <li>• Von Böckh und Wetzel. Wärmeübertragung: Grundlagen und Praxis, Springer, 2011.</li> <li>• Baehr und Stephan. Wärme- und Stoffübertragung. Springer, 2009.</li> <li>• de Vos. Thermodynamics of solar energy conversion. Wiley-VCH, 2008.</li> <li>• Mohr, Svoboda und Unger. Praxis solarthermischer Kraftwerke. Springer, 1999.</li> </ul> |

| Course L0015: Solar Power Generation |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|--------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                           | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Hrs/wk</b>                        | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>CP</b>                            | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Workload in Hours</b>             | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Lecturer</b>                      | Martin Schlecht, Prof. Alf Mews, Roman Fritsches-Baguhl                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Language</b>                      | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Cycle</b>                         | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Content</b>                       | <p>Photovoltaics:</p> <ol style="list-style-type: none"> <li>1. Introduction</li> <li>2. Primary energies and consumption, available solar energy</li> <li>3. Physics of the ideal solar cell</li> <li>4. Light absorption, PN transition, characteristic sizes of the solar cell, efficiency</li> <li>5. Physics of the real solar cell</li> <li>6. Charge carrier recombination, characteristic curves, barrier layer recombination, equivalent circuit diagram</li> <li>7. Increasing efficiency</li> <li>8. Methods for increasing the quantum yield and reducing recombination</li> <li>9. Hetero- and tandem structures</li> <li>10. Heterojunction, Schottky, electrochemical, MIS and SIS cell, tandem cell</li> <li>11. Concentrator cells</li> <li>12. Concentrator optics and tracking systems, concentrator cells</li> <li>13. Technology and properties: solar cell types, manufacturing, monocrystalline silicon and gallium arsenide, polycrystalline silicon and silicon thin film cells, thin film cells on carriers (amorphous silicon, CIS, electrochemical cells)</li> <li>14. Modules</li> <li>15. Switches</li> </ol> <p>Concentrating solar power plants:</p> <ol style="list-style-type: none"> <li>1. Introduction</li> <li>2. Point focused technologies</li> <li>3. Line focused technologies</li> <li>4. Design of CSP projects</li> </ol>                                         |
| <b>Literature</b>                    | <ul style="list-style-type: none"> <li>• A. Götzberger, B. Voß, J. Knobloch: Sonnenenergie: Photovoltaik, Teubner Studienskripten, Stuttgart, 1995</li> <li>• A. Götzberger: Sonnenenergie: Photovoltaik : Physik und Technologie der Solarzelle, Teubner Stuttgart, 1994</li> <li>• H.-J. Lewerenz, H. Jungblut: Photovoltaik, Springer, Berlin, Heidelberg, New York, 1995</li> <li>• A. Götzberger: Photovoltaic solar energy generation, Springer, Berlin, 2005</li> <li>• C. Hu, R. M. White: Solar Cells, Mc Graw Hill, New York, 1983</li> <li>• H.-G. Wagemann: Grundlagen der photovoltaischen Energiewandlung: Solarstrahlung, Halbleitereigenschaften und Solarzellenkonzepte, Teubner, Stuttgart, 1994</li> <li>• R. J. van Overstraeten, R.P. Mertens: Physics, technology and use of photovoltaics, Adam Hilger Ltd, Bristol and Boston, 1986</li> <li>• B. O. Seraphin: Solar energy conversion Topics of applied physics V 01 31, Springer, Berlin, Heidelberg, New York, 1995</li> <li>• P. Würfel: Physics of Solar cells, Principles and new concepts, Wiley-VCH, Weinheim 2005</li> <li>• U. Rindelhardt: Photovoltaische Stromversorgung, Teubner-Reihe Umwelt, Stuttgart 2001</li> <li>• V. Quaschnig: Regenerative Energiesysteme, Hanser, München, 2003</li> <li>• G. Schmitz: Regenerative Energien, Ringvorlesung TU Hamburg-Harburg 1994/95, Institut für Energietechnik</li> </ul> |

| Module M1308: Modelling and Technical Design of Bio Refinery Processes        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |        |    |
|-------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|----|
| Courses                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |        |    |
| Title                                                                         | Type                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Hrs/wk | CP |
| Biorefineries - Technical Design and Optimization (L1832)                     | Project-/problem-based Learning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 3      | 3  |
| CAPE in Energy Engineering (L0022)                                            | Projection Course                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 3      | 3  |
| <b>Module Responsible</b>                                                     | Prof. Martin Kaltschmitt                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |        |    |
| <b>Admission Requirements</b>                                                 | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |        |    |
| <b>Recommended Previous Knowledge</b>                                         | Bachelor degree in Process Engineering, Bioprocess Engineering or Energy- and Environmental Engineering                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |        |    |
| <b>Educational Objectives</b>                                                 | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |        |    |
| <b>Professional Competence</b><br><i>Knowledge</i><br><br><i>Skills</i>       | <p>The tudents can completely design a technical process including mass and energy balances, calculation and layout of different process devices, layout of measurement- and control systems as well as modeling of the overall process.</p> <p>Furthermore, they can describe the basics of the general procedure for the processing of modeling tasks, especially with ASPEN PLUS ® and ASPEN CUSTOM MODELER ®.</p> <p>Students are able to simulate and solve scientific task in the context of renewable energy technologies by:</p> <ul style="list-style-type: none"> <li>• development of modul-comprehensive approaches for the dimensioning and design of production processes</li> <li>• evaluating alternatives input parameter to solve the particular task even with incomplete information,</li> <li>• a systematic documentation of the work results in form of a written version, the presentation itself and the defense of contents.</li> </ul> <p>They can use the ASPEN PLUS ® and ASPEN CUSTOM MODELER ® for modeling energy systems and to evaluate the simulation solutions.</p> <p>Through active discussions of various topics within the seminars and exercises of the module, students improve their understanding and the application of the theoretical background and are thus able to transfer what they have learned in practice.</p> |        |    |
| <b>Personal Competence</b><br><i>Social Competence</i><br><br><i>Autonomy</i> | <p>Students can</p> <ul style="list-style-type: none"> <li>• respectfully work together as a team with around 2-3 members,</li> <li>• participate in subject-specific and interdisciplinary discussions in the area of dimensioning and design of production processes, and can develop cooperated solutions,</li> <li>• defend their own work results in front of fellow students and</li> </ul> <p>assess the performance of fellow students in comparison to their own performance. Furthermore, they can accept professional constructive criticism.</p> <p>Students can independently tap knowledge regarding to the given task. They are capable, in consultation with supervisors, to assess their learning level and define further steps on this basis. Furthermore, they can define targets for new application-or research-oriented duties in accordance with the potential social, economic and cultural impact.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                      |        |    |
| <b>Workload in Hours</b>                                                      | Independent Study Time 96, Study Time in Lecture 84                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |    |
| <b>Credit points</b>                                                          | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |        |    |
| <b>Course achievement</b>                                                     | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |        |    |
| <b>Examination</b>                                                            | Written elaboration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |    |
| <b>Examination duration and scale</b>                                         | Written report incl. presentation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |        |    |
| <b>Assignment for the Following Curricula</b>                                 | <p>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory</p> <p>Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory</p> <p>Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory</p> <p>Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory</p> <p>Environmental Engineering: Core Qualification: Elective Compulsory</p> <p>Renewable Energies: Core Qualification: Compulsory</p> <p>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |    |

| Course L1832: Biorefineries - Technical Design and Optimization |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-----------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                      | Project-/problem-based Learning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Hrs/wk</b>                                                   | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>CP</b>                                                       | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Workload in Hours</b>                                        | Independent Study Time 48, Study Time in Lecture 42                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Lecturer</b>                                                 | Prof. Oliver Lüdtkke                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Language</b>                                                 | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Cycle</b>                                                    | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Content</b>                                                  | <p><b>I. Repetition of engineering basics</b></p> <ol style="list-style-type: none"> <li>1. Shell and tube heat exchangers</li> <li>2. Steam generators and refrigerating machines</li> <li>3. Pumps and turbines</li> <li>4. Flow in piping networks</li> <li>5. Pumping and mixing of non-newtonian fluids</li> <li>6. Requirements to a detailed layout plan</li> </ol> <p><b>II. Calculation:</b></p> <ol style="list-style-type: none"> <li>1. Planning and design of a specific bio-refinery plant section, such as Ethanol distillation and fermentation. This is based on empirical value of a real, industrial plant. <ul style="list-style-type: none"> <li>◦ Mass and energy balances (Aspen)</li> <li>◦ Equipment design (heat exchangers, pumps, pipes, tanks, etc.) (</li> <li>◦ Isolation, wall thickness and material selection</li> <li>◦ Energy demand (electrical, heat or cooling), design of steam boilers and appliances</li> <li>◦ Selection of fittings, measuring instruments and safety equipment</li> <li>◦ Definition of main control loops</li> </ul> </li> <li>2. Hereby, the dependencies of transport phenomena between certain plant sections become evident and methods of calculation are introduced.</li> <li>3. In Detail Engineering , it is focused on aspects of plant engineering planning that are relevant for the subsequent construction of the plant.</li> <li>4. Depending of time requirement and group size a cost estimation and preparation of a complete R&amp;I flow chart can be implemented as well.</li> </ol> |
| <b>Literature</b>                                               | <p>Perry, R.;Green, R.: Perry's Chemical Engineers' Handbook, 8<sup>th</sup> Edition, McGraw Hill Professional, 2007</p> <p>Sinnot, R. K.: Chemical Engineering Design, Elsevier, 2014</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |

| Course L0022: CAPE in Energy Engineering |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                               | Projection Course                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Hrs/wk</b>                            | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>CP</b>                                | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Workload in Hours</b>                 | Independent Study Time 48, Study Time in Lecture 42                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Lecturer</b>                          | Prof. Martin Kaltschmitt                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Language</b>                          | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Cycle</b>                             | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Content</b>                           | <ul style="list-style-type: none"> <li>• CAPE = <i>Computer-Aided-Project-Engineering</i></li> <li>• INTRODUCTION TO THE THEORY <ul style="list-style-type: none"> <li>◦ Classes of simulation programs</li> <li>◦ Sequential modular approach</li> <li>◦ Equation-oriented approach</li> <li>◦ Simultaneous modular approach</li> <li>◦ General procedure for the processing of modeling tasks</li> <li>◦ Special procedure for solving models with repatriations</li> </ul> </li> <li>• COMPUTER EXERCISES renewable energy projects WITH ASPEN PLUS ® AND ASPEN CUSTOM MODELER ® <ul style="list-style-type: none"> <li>◦ Scope, potential and limitations of Aspen Plus ® and Aspen Custom Modeler ®</li> <li>◦ Use of integrated databases for material data</li> <li>◦ Methods for estimating non-existent physical property data</li> <li>◦ Use of model libraries and Process Synthesis</li> <li>◦ Application of design specifications and sensitivity analyzes</li> <li>◦ Solving optimization problems</li> </ul> </li> </ul> <p>Within the seminar, the various tasks are actively discussed and applied to various cases of application.</p> |
| <b>Literature</b>                        | <ul style="list-style-type: none"> <li>• Aspen Plus® - Aspen Plus User Guide</li> <li>• William L. Luyben; Distillation Design and Control Using Aspen Simulation; ISBN-10: 0-471-77888-5</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

| Module M1878: Sustainable energy from wind and water                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |        |    |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|----|
| Courses                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |        |    |
| Title                                                                                                                                                        | Type                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Hrs/wk | CP |
| Offshore Geotechnical Engineering (L0067)                                                                                                                    | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1      | 1  |
| Hydro Power Use (L0013)                                                                                                                                      | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1      | 1  |
| Wind Turbine Plants (L0011)                                                                                                                                  | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 2      | 3  |
| Wind Energy Use - Focus Offshore (L0012)                                                                                                                     | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1      | 1  |
| <b>Module Responsible</b>                                                                                                                                    | Dr. Marvin Scherzinger                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |    |
| <b>Admission Requirements</b>                                                                                                                                | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |        |    |
| <b>Recommended Previous Knowledge</b>                                                                                                                        | Module: Technical Thermodynamics I,<br>Module: Technical Thermodynamics II,<br>Module: Fundamentals of Fluid Mechanics                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |    |
| <b>Educational Objectives</b>                                                                                                                                | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |        |    |
| <b>Professional Competence</b><br><i>Knowledge</i><br><br><i>Skills</i><br><br><b>Personal Competence</b><br><i>Social Competence</i><br><br><i>Autonomy</i> | <p>By ending this module students can explain in detail knowledge of wind turbines with a particular focus of wind energy use in offshore conditions and can critical comment these aspects in consideration of current developments. Furthermore, they are able to describe fundamentally the use of water power to generate electricity. The students reproduce and explain the basic procedure in the implementation of renewable energy projects in countries outside Europe.</p> <p>Through active discussions of various topics within the seminar of the module, students improve their understanding and the application of the theoretical background and are thus able to transfer what they have learned in practice.</p> <p>Students are able to apply the acquired theoretical foundations on exemplary water or wind power systems and evaluate and assess technically the resulting relationships in the context of dimensioning and operation of these energy systems. They can in compare critically the special procedure for the implementation of renewable energy projects in countries outside Europe with the in principle applied approach in Europe and can apply this procedure on exemplary theoretical projects.</p> <p>Students can discuss scientific tasks subject-specificly and multidisciplinary within a seminar.</p> <p>Students can independently exploit sources in the context of the emphasis of the lecture material to clear the contents of the lecture and to acquire the particular knowledge about the subject area.</p>                                                                                    |        |    |
| <b>Workload in Hours</b>                                                                                                                                     | Independent Study Time 110, Study Time in Lecture 70                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |        |    |
| <b>Credit points</b>                                                                                                                                         | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |        |    |
| <b>Course achievement</b>                                                                                                                                    | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |        |    |
| <b>Examination</b>                                                                                                                                           | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |        |    |
| <b>Examination duration and scale</b>                                                                                                                        | 180 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |    |
| <b>Assignment for the Following Curricula</b>                                                                                                                | Civil Engineering: Specialisation Structural Engineering: Elective Compulsory<br>Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory<br>Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Specialisation Product Development: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Specialisation Production: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Specialisation Materials: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Production: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Materials: Elective Compulsory<br>Renewable Energies: Core Qualification: Compulsory<br>Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Cities: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Water: Elective Compulsory |        |    |

| Course L0067: Offshore Geotechnical Engineering |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                      | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Hrs/wk</b>                                   | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>CP</b>                                       | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Workload in Hours</b>                        | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Lecturer</b>                                 | Dr. Jan Dührkop                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Language</b>                                 | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Cycle</b>                                    | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Content</b>                                  | <ul style="list-style-type: none"> <li>• Overview and Introduction Offshore Geotechnics</li> <li>• Introduction to Soil Mechanics</li> <li>• Offshore soil investigation</li> <li>• Focus on cyclical effects</li> <li>• Geotechnical design of offshore foundations</li> <li>• Monopiles</li> <li>• Jackets</li> <li>• Heavyweight foundations</li> <li>• Geotechnical preliminary exploration for the use of lift boats and platforms</li> </ul>                                     |
| <b>Literature</b>                               | <ul style="list-style-type: none"> <li>• Randolph, M. and Gourvenec, S (2011): Offshore Geotechnical Engineering. Spon Press.</li> <li>• Poulos H.G. (1988): Marine Geotechnics. Unwin Hyman, London</li> <li>• BSH-Standard Baugrunderkundung für Offshore-Windenergieparks</li> <li>• Lesny K. (2010): Foundations for Offshore Wind Turbines. VGE Verlag, Essen.</li> <li>• EA-Pfähle (2012): Empfehlungen des Arbeitskreises Pfähle der DGGT. Ernst &amp; Sohn, Berlin.</li> </ul> |

| Course L0013: Hydro Power Use |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                    | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Hrs/wk</b>                 | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>CP</b>                     | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Workload in Hours</b>      | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Lecturer</b>               | Prof. Stephan Theobald                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Language</b>               | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Cycle</b>                  | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Content</b>                | <ul style="list-style-type: none"> <li>• Introduction, importance of water power in the national and global context</li> <li>• Physical basics: Bernoulli's equation, usable height of fall, hydrological measures, loss mechanisms, efficiencies</li> <li>• Classification of Hydropower: Flow and Storage hydropower, low and high pressure systems</li> <li>• Construction of hydroelectric power plants: description of the individual components and their technical system interaction</li> <li>• Structural engineering components; representation of dams, weirs, dams, power houses, computer systems, etc.</li> <li>• Energy Technical Components: Illustration of the different types of hydraulic machinery, generators and grid connection</li> <li>• Hydropower and the Environment</li> <li>• Examples from practice</li> </ul> |
| <b>Literature</b>             | <ul style="list-style-type: none"> <li>• Schröder, W.; Euler, G.; Schneider, K.: Grundlagen des Wasserbaus; Werner, Düsseldorf, 1999, 4. Auflage</li> <li>• Quaschnig, V.: Regenerative Energiesysteme: Technologie - Berechnung - Simulation; Carl Hanser, München, 2011, 7. Auflage</li> <li>• Giesecke, J.; Heimerl, S.; Mosony, E.: Wasserkraftanlagen - Planung, Bau und Betrieb; Springer, Berlin, Heidelberg, 2009, 5. Auflage</li> <li>• von König, F.; Jehle, C.: Bau von Wasserkraftanlagen - Praxisbezogene Planungsunterlagen; C. F. Müller, Heidelberg, 2005, 4. Auflage</li> <li>• Strobl, T.; Zunic, F.: Wasserbau: Aktuelle Grundlagen - Neue Entwicklungen; Springer, Berlin, Heidelberg, 2006</li> </ul>                                                                                                                     |

| Course L0011: Wind Turbine Plants |                                                                                                                                                                                                                                                                                                                                                                                                                     |
|-----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                        | Lecture                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Hrs/wk</b>                     | 2                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>CP</b>                         | 3                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Workload in Hours</b>          | Independent Study Time 62, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Lecturer</b>                   | Matthias Schubert                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Language</b>                   | DE                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Cycle</b>                      | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Content</b>                    | <ul style="list-style-type: none"> <li>• Historical development</li> <li>• Wind: origins, geographic and temporal distribution, locations</li> <li>• Power coefficient, rotor thrust</li> <li>• Aerodynamics of the rotor</li> <li>• Operating performance</li> <li>• Power limitation, partial load, pitch and stall control</li> <li>• Plant selection, yield prediction, economy</li> <li>• Excursion</li> </ul> |
| <b>Literature</b>                 | Gasch, R., Windkraftanlagen, 4. Auflage, Teubner-Verlag, 2005                                                                                                                                                                                                                                                                                                                                                       |

| Course L0012: Wind Energy Use - Focus Offshore |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                     | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Hrs/wk</b>                                  | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>CP</b>                                      | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Workload in Hours</b>                       | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Lecturer</b>                                | Prof. Martin Skiba                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Language</b>                                | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Cycle</b>                                   | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Content</b>                                 | <ul style="list-style-type: none"> <li>• Introduction, importance of offshore wind power generation, Specific requirements for offshore engineering</li> <li>• Physical fundamentals for utilization of wind energy</li> <li>• Design and operation of offshore wind turbines, presentation of different concepts of offshore wind turbines, representation of the individual system components and their system-technical relationships</li> <li>• Foundation engineering, offshore site investigation, presentation of different concepts of offshore foundation structures, planning and fabrication of foundation structures</li> <li>• Electrical infrastructure of an offshore wind farm, Inner Park cabling, offshore substation, grid connection</li> <li>• Installation of offshore wind farms, installation techniques and auxiliary devices, construction logistics</li> <li>• Development and planning of offshore wind farms</li> <li>• Operation and optimization of offshore wind farms</li> <li>• Day excursion</li> </ul> |
| <b>Literature</b>                              | <ul style="list-style-type: none"> <li>• Gasch, R.; Twele, J.: Windkraftanlagen - Grundlagen, Entwurf, Planung und Betrieb; Vieweg + Teubner, Stuttgart, 2007, 7. Auflage</li> <li>• Molly, J. P.: Windenergie - Theorie, Anwendung, Messung; C. F. Müller, Heidelberg, 1997, 3. Auflage</li> <li>• Hau, E.: Windkraftanlagen; Springer, Berlin, Heidelberg, 2008, 4. Auflage</li> <li>• Heier, S.: Windkraftanlagen - Systemauslegung, Integration und Regelung; Vieweg + Teubner, Stuttgart, 2009, 5. Auflage</li> <li>• Jarass, L.; Obermair, G.M.; Voigt, W.: Windenergie: Zuverlässige Integration in die Energieversorgung; Springer, Berlin, Heidelberg, 2009, 2. Auflage</li> </ul>                                                                                                                                                                                                                                                                                                                                                |



| Module M2157: Technologies for electric and hydrogen mobility                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                        |    |
|-------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|----|
| Courses                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                        |    |
| Title                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Typ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Hrs/wk                                                                                                                 | CP |
| Applied Fuel Cell Technology (L1831)                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2                                                                                                                      | 2  |
| Fuel Cells, Batteries, and Gas Storage: New Materials for Energy Production and Storage (L0021) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2                                                                                                                      | 2  |
| Electro mobility (L1833)                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2                                                                                                                      | 2  |
| Module Responsible                                                                              | Prof. Martin Kaltschmitt                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                        |    |
| Admission Requirements                                                                          | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                        |    |
| Recommended Previous Knowledge                                                                  | Module: Technical Thermodynamics I                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                        |    |
|                                                                                                 | Module: Technical Thermodynamics II                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                        |    |
| Educational Objectives                                                                          | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                        |    |
| Professional Competence                                                                         | Knowledge                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Students are able to describe the processes in energy trading and the design of energy markets and can critically evaluate them in relation to current subject specific problems. Furthermore, they are able to explain the basics of thermodynamics of electrochemical energy conversion in fuel cells and can establish and explain the relationship to different types of fuel cells and their respective structure. Students can compare this technology with other energy storage options. In addition, students can give an overview of the procedure and the energetic involvement of deep geothermal energy.                                                                                                                                                                                                             |                                                                                                                        |    |
|                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                        |    |
|                                                                                                 | Skills                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Students can apply the learned knowledge of storage systems for excessive energy to explain for various energy systems different approaches to ensure a secure energy supply. In particular, they can plan and calculate domestic, commercial and industrial heating equipment using energy storage systems in an energy-efficient way and can assess them in relation to complex power systems. In this context, students can assess the potential and limits of geothermal power plants and explain their operating mode.<br><br>Furthermore, the students are able to explain the procedures and strategies for marketing of energy and apply it in the context of other modules on renewable energy projects. In this context they can unassistedly carry out analysis and evaluations of energie markets and energy trades. |                                                                                                                        |    |
|                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                        |    |
|                                                                                                 | Personal Competence                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Social Competence                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Students are able to discuss issues in the thematic fields in the renewable energy sector addressed within the module. |    |
|                                                                                                 | Autonomy                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Students can independently exploit sources , acquire the particular knowledge about the subject area and transform it to new questions.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                        |    |
| Workload in Hours                                                                               | Independent Study Time 96, Study Time in Lecture 84                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                        |    |
| Credit points                                                                                   | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                        |    |
| Course achievement                                                                              | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                        |    |
| Examination                                                                                     | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                        |    |
| Examination duration and scale                                                                  | 3 hours written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                        |    |
| Assignment for the Following Curricula                                                          | Aircraft Systems Engineering: Core Qualification: Elective Compulsory<br>International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory<br>International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory<br>International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory<br>Aeronautics: Core Qualification: Elective Compulsory<br>Renewable Energies: Core Qualification: Compulsory<br>Water and Environmental Engineering: Specialisation Water: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Elective Compulsory |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                        |    |

| Course L1831: Applied Fuel Cell Technology |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|--------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Type</b>                                | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Hrs/wk</b>                              | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>CP</b>                                  | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Workload in Hours</b>                   | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Lecturer</b>                            | Prof. Klaus Bonhoff                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Language</b>                            | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Cycle</b>                               | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Content</b>                             | The lecture provide an insight into the various possibilities of fuel cells in the energy system (electricity, heat and transport). These are presented and discussed for individual fuel types and application-oriented requirements; also compared with alternative technologies in the system. These different possibilities will be presented regardind the state-of-the-art development of the technologies and exemplary applications from Germany and worldwide. Also the emerging trends and lines of development will be discussed. Besides to the technical aspects, which are the focus of the event, also energy, environmental and industrial policy aspects are discussed - also in the context of changing circumstances in the German and international energy system. |
| <b>Literature</b>                          | Vorlesungsunterlagen                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

| Course L0021: Fuel Cells, Batteries, and Gas Storage: New Materials for Energy Production and Storage |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|-------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                                                            | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Hrs/wk</b>                                                                                         | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>CP</b>                                                                                             | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Workload in Hours</b>                                                                              | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Lecturer</b>                                                                                       | Prof. Michael Fröba                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Language</b>                                                                                       | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Cycle</b>                                                                                          | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Content</b>                                                                                        | <ol style="list-style-type: none"> <li>1. Introduction to electrochemical energy conversion</li> <li>2. Function and structure of electrolyte</li> <li>3. Low-temperature fuel cell <ul style="list-style-type: none"> <li>◦ Types</li> <li>◦ Thermodynamics of the PEM fuel cell</li> <li>◦ Cooling and humidification strategy</li> </ul> </li> <li>4. High-temperature fuel cell <ul style="list-style-type: none"> <li>◦ The MCFC</li> <li>◦ The SOFC</li> <li>◦ Integration Strategies and partial reforming</li> </ul> </li> <li>5. Fuels <ul style="list-style-type: none"> <li>◦ Supply of fuel</li> <li>◦ Reforming of natural gas and biogas</li> <li>◦ Reforming of liquid hydrocarbons</li> </ul> </li> <li>6. Energetic Integration and control of fuel cell systems</li> </ol> |
| <b>Literature</b>                                                                                     | <ul style="list-style-type: none"> <li>• Hamann, C.; Vielstich, W.: Elektrochemie 3. Aufl.; Weinheim: Wiley - VCH, 2003</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

| Course L1833: Electro mobility |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|--------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                     | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Hrs/wk</b>                  | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>CP</b>                      | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Workload in Hours</b>       | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Lecturer</b>                | Prof. Klaus Bonhoff                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Language</b>                | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Cycle</b>                   | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Content</b>                 | <ul style="list-style-type: none"> <li>• Introduction and environment</li> <li>• Definition of electric vehicles</li> <li>• Excursus: Electric vehicles with fuel cell</li> <li>• Market uptake of electric cars</li> <li>• Political / Regulatory Framework</li> <li>• Historical Review</li> <li>• Electric vehicle portfolio / application examples</li> <li>• Mild hybrids with 48 volt technology</li> <li>• Lithium-ion battery incl. Costs, roadmap, production, raw materials</li> <li>• Vehicle Integration</li> <li>• Energy consumption of electric cars</li> <li>• Battery life</li> <li>• Charging Infrastructure</li> <li>• Electric road transport</li> <li>• Electric public transport</li> <li>• Battery Safety</li> </ul> |
| <b>Literature</b>              | Vorlesungsunterlagen/ lecture material                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

| Module M0742: Thermal Energy Systems          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |        |    |
|-----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|----|
| Courses                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |        |    |
| Title                                         | Type                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Hrs/wk | CP |
| Thermal Energy Systems (L0023)                | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 3      | 5  |
| Thermal Energy Systems (L0024)                | Recitation Section (large)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 1      | 1  |
| <b>Module Responsible</b>                     | Prof. Arne Speerforck                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |    |
| <b>Admission Requirements</b>                 | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |        |    |
| <b>Recommended Previous Knowledge</b>         | Technical Thermodynamics I, II, Fluid Dynamics, Heat Transfer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |        |    |
| <b>Educational Objectives</b>                 | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |        |    |
| <b>Professional Competence</b>                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |        |    |
| <i>Knowledge</i>                              | Students know the different energy conversion stages and the difference between efficiency and annual efficiency. They have increased knowledge in heat and mass transfer, especially in regard to buildings and mobile applications. They are familiar with German energy saving code and other technical relevant rules. They know to differ different heating systems in the domestic and industrial area and how to control such heating systems. They are able to model a furnace and to calculate the transient temperatures in a furnace. They have the basic knowledge of emission formations in the flames of small burners and how to conduct the flue gases into the atmosphere. They are able to model thermodynamic systems with object oriented languages.                                 |        |    |
| <i>Skills</i>                                 | Students are able to calculate the heating demand for different heating systems and to choose the suitable components. They are able to calculate a pipeline network and have the ability to perform simple planning tasks, regarding solar energy. They can write Modelica programs and can transfer research knowledge into practice. They are able to perform scientific work in the field of thermal engineering.                                                                                                                                                                                                                                                                                                                                                                                    |        |    |
| <b>Personal Competence</b>                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |        |    |
| <i>Social Competence</i>                      | In lectures and exercises, the students can use many examples and experiments to discuss in small groups in a goal-oriented manner, develop a solution and present it. Within the exercises, the students can independently develop further questions and work out targeted solutions.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |    |
| <i>Autonomy</i>                               | Students are able to define tasks independently, to develop the necessary knowledge themselves based on the knowledge they have received, and to use suitable means for implementation. In the exercises, the students discuss the methods taught in the lectures using complex tasks and critically analyze the results.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |        |    |
| <b>Workload in Hours</b>                      | Independent Study Time 124, Study Time in Lecture 56                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |        |    |
| <b>Credit points</b>                          | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |        |    |
| <b>Course achievement</b>                     | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |        |    |
| <b>Examination</b>                            | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |        |    |
| <b>Examination duration and scale</b>         | 60 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |    |
| <b>Assignment for the Following Curricula</b> | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Technical Complementary Course: Elective Compulsory<br>Energy Systems: Core Qualification: Compulsory<br>International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Core Qualification: Elective Compulsory<br>Product Development, Materials and Production: Core Qualification: Elective Compulsory<br>Renewable Energies: Core Qualification: Compulsory<br>Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |        |    |

| Course L0023: Thermal Energy Systems |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|--------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                           | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Hrs/wk</b>                        | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>CP</b>                            | 5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Workload in Hours</b>             | Independent Study Time 108, Study Time in Lecture 42                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Lecturer</b>                      | Prof. Gerhard Schmitz, Prof. Arne Speerforck                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Language</b>                      | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Cycle</b>                         | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Content</b>                       | <p>1. Introduction</p> <p>2. Fundamentals of Thermal Engineering 2.1 Heat Conduction 2.2 Convection 2.3 Radiation 2.4 Heat transition 2.5 Combustion parameters 2.6 Electrical heating 2.7 Water vapor transport</p> <p>3. Heating Systems 3.1 Warm water heating systems 3.2 Warm water supply 3.3 piping calculation 3.4 boilers, heat pumps, solar collectors 3.5 Air heating systems 3.6 radiative heating systems</p> <p>4. Thermal treatment systems 4.1 Industrial furnaces 4.2 Melting furnaces 4.3 Drying plants 4.4 Emission control 4.5 Chimney calculation 4.6 Energy measuring</p> <p>5. Laws and standards 5.1 Buildings 5.2 Industrial plants</p> |
| <b>Literature</b>                    | <ul style="list-style-type: none"> <li>• Schmitz, G.: Klimaanlagen, Skript zur Vorlesung</li> <li>• VDI Wärmeatlas, 11. Auflage, Springer Verlag, Düsseldorf 2013</li> <li>• Herwig, H.; Moschallski, A.: Wärmeübertragung, Vieweg+Teubner Verlag, Wiesbaden 2009</li> <li>• Recknagel, H.; Sprenger, E.; Schrammek, E.-R.: Taschenbuch für Heizung- und Klimatechnik 2013/2014, 76. Auflage, Deutscher Industrieverlag, 2013</li> </ul>                                                                                                                                                                                                                         |

| Course L0024: Thermal Energy Systems |                                                     |
|--------------------------------------|-----------------------------------------------------|
| <b>Typ</b>                           | Recitation Section (large)                          |
| <b>Hrs/wk</b>                        | 1                                                   |
| <b>CP</b>                            | 1                                                   |
| <b>Workload in Hours</b>             | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>                      | Prof. Arne Speerforck                               |
| <b>Language</b>                      | DE                                                  |
| <b>Cycle</b>                         | WiSe                                                |
| <b>Content</b>                       | See interlocking course                             |
| <b>Literature</b>                    | See interlocking course                             |

## Specialization Bioenergy Systems

In the specialization "Bioenergy systems" advanced knowledge for the energetic utilisation of biomass is provided. This implicates, inter alia, the processing and use of wood as an energy resource, but also an understanding about procedures and concepts which enable energy recovery from waste.

### Module M1343: Structure and properties of fibre-polymer-composites

| Courses                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |        |    |
|--------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|----|
| Title                                                        | Typ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Hrs/wk | CP |
| Structure and properties of fibre-polymer-composites (L1894) | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2      | 3  |
| Structure and properties of fibre-polymer-composites (L2614) | Project-/problem-based Learning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 2      | 2  |
| Structure and properties of fibre-polymer-composites (L2613) | Recitation Section (large)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1      | 1  |
| <b>Module Responsible</b>                                    | Prof. Bodo Fiedler                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |        |    |
| <b>Admission Requirements</b>                                | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |        |    |
| <b>Recommended Previous Knowledge</b>                        | Basics: chemistry / physics / materials science                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |        |    |
| <b>Educational Objectives</b>                                | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |        |    |
| <b>Professional Competence</b><br><i>Knowledge</i>           | Students can use the knowledge of fiber-reinforced composites (FRP) and its constituents to play (fiber / matrix) and define the necessary testing and analysis.<br><br>They can explain the complex relationships structure-property relationship and the interactions of chemical structure of the polymers, their processing with the different fiber types, including to explain neighboring contexts (e.g. sustainability, environmental protection).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |        |    |
| <i>Skills</i>                                                | Students are capable of <ul style="list-style-type: none"> <li>• using standardized calculation methods in a given context to mechanical properties (modulus, strength) to calculate and evaluate the different materials.</li> <li>• approximate sizing using the network theory of the structural elements implement and evaluate.</li> <li>• selecting appropriate solutions for mechanical recycling problems and sizing example stiffness, corrosion resistance.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |        |    |
| <b>Personal Competence</b><br><i>Social Competence</i>       | Students can <ul style="list-style-type: none"> <li>• arrive at funded work results in heterogenius groups and document them.</li> <li>• provide appropriate feedback and handle feedback on their own performance constructively.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |    |
| <i>Autonomy</i>                                              | Students are able to <ul style="list-style-type: none"> <li>- assess their own strengths and weaknesses.</li> <li>- assess their own state of learning in specific terms and to define further work steps on this basis.</li> <li>- assess possible consequences of their professional activity.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |        |    |
| <b>Workload in Hours</b>                                     | Independent Study Time 110, Study Time in Lecture 70                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |        |    |
| <b>Credit points</b>                                         | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |        |    |
| <b>Course achievement</b>                                    | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |        |    |
| <b>Examination</b>                                           | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |    |
| <b>Examination duration and scale</b>                        | 90 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |        |    |
| <b>Assignment for the Following Curricula</b>                | Aircraft Systems Engineering: Core Qualification: Elective Compulsory<br>International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory<br>Aeronautics: Core Qualification: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Specialisation Product Development: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Specialisation Production: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Specialisation Materials: Compulsory<br>Materials Science and Engineering: Specialisation Engineering Materials: Elective Compulsory<br>Mechanical Engineering and Management: Core Qualification: Compulsory<br>Biomedical Engineering: Specialisation Implants and Endoprotheses: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Production: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Materials: Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Materials Science: Elective Compulsory |        |    |

| Course L1894: Structure and properties of fibre-polymer-composites |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|--------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                         | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Hrs/wk</b>                                                      | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>CP</b>                                                          | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Workload in Hours</b>                                           | Independent Study Time 62, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Lecturer</b>                                                    | Prof. Bodo Fiedler                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Language</b>                                                    | EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Cycle</b>                                                       | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Content</b>                                                     | <ul style="list-style-type: none"> <li>- Microstructure and properties of the matrix and reinforcing materials and their interaction</li> <li>- Development of composite materials</li> <li>- Mechanical and physical properties</li> <li>- Mechanics of Composite Materials</li> <li>- Laminate theory</li> <li>- Test methods</li> <li>- Non destructive testing</li> <li>- Failure mechanisms</li> <li>- Theoretical models for the prediction of properties</li> <li>- Application</li> </ul> |
| <b>Literature</b>                                                  | Hall, Clyne: Introduction to Composite materials, Cambridge University Press<br>Daniel, Ishai: Engineering Mechanics of Composites Materials, Oxford University Press<br>Mallick: Fibre-Reinforced Composites, Marcel Dekker, New York                                                                                                                                                                                                                                                            |

| Course L2614: Structure and properties of fibre-polymer-composites |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|--------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                         | Project-/problem-based Learning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Hrs/wk</b>                                                      | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>CP</b>                                                          | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Workload in Hours</b>                                           | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Lecturer</b>                                                    | Prof. Bodo Fiedler                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Language</b>                                                    | DE/EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Cycle</b>                                                       | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Content</b>                                                     | <p>The students receive the assignment in the form of a material design for test bodies made of fibre composites. Technical and normative requirements are listed in the assignment, all other required information comes from the lectures and exercises or the respective documents (electronically and in conversation).</p> <p>The procedure is specified in a milestone plan and enables the students to plan subtasks and thus work continuously. At the end of the project, different test specimens were tested in tensile or bending tests.</p> <p>In the individual project meetings, the conception (discussion of requirements and risks) is scrutinised. The calculations are analysed, the production methods are evaluated and determined. Materials are selected and the test specimens are manufactured according to standards. The quality and mechanical properties are checked and classified. At the end, a final report is prepared and the results are presented to all participants in the form of a presentation and discussed.</p> <p>Translated with <a href="https://www.DeepL.com/Translator">www.DeepL.com/Translator</a> (free version)</p> |
| <b>Literature</b>                                                  | Hall, Clyne: Introduction to Composite materials, Cambridge University Press<br>Daniel, Ishai: Engineering Mechanics of Composites Materials, Oxford University Press<br>Mallick: Fibre-Reinforced Composites, Marcel Dekker, New York                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

| Course L2613: Structure and properties of fibre-polymer-composites |                                                                                                                                                                                                                                        |
|--------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                         | Recitation Section (large)                                                                                                                                                                                                             |
| <b>Hrs/wk</b>                                                      | 1                                                                                                                                                                                                                                      |
| <b>CP</b>                                                          | 1                                                                                                                                                                                                                                      |
| <b>Workload in Hours</b>                                           | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                    |
| <b>Lecturer</b>                                                    | Prof. Bodo Fiedler                                                                                                                                                                                                                     |
| <b>Language</b>                                                    | EN                                                                                                                                                                                                                                     |
| <b>Cycle</b>                                                       | SoSe                                                                                                                                                                                                                                   |
| <b>Content</b>                                                     | <p>The contents of the lecture are repeated and deepened using practical examples.</p> <p>Calculations are carried out together or individually, and the results are discussed critically.</p>                                         |
| <b>Literature</b>                                                  | Hall, Clyne: Introduction to Composite materials, Cambridge University Press<br>Daniel, Ishai: Engineering Mechanics of Composites Materials, Oxford University Press<br>Mallick: Fibre-Reinforced Composites, Marcel Dekker, New York |

| Module M0896: Bioprocess and Biosystems Engineering |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |        |    |
|-----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|----|
| Courses                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |        |    |
| Title                                               | Type                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Hrs/wk | CP |
| Bioreactor Design and Operation (L1034)             | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2      | 2  |
| Bioreactors and Biosystems Engineering (L1037)      | Project-/problem-based Learning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1      | 2  |
| Biosystems Engineering (L1036)                      | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2      | 2  |
| <b>Module Responsible</b>                           | Prof. Anna-Lena Heins                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |        |    |
| <b>Admission Requirements</b>                       | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |        |    |
| <b>Recommended Previous Knowledge</b>               | Knowledge of bioprocess engineering and process engineering at bachelor level                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |    |
| <b>Educational Objectives</b>                       | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |        |    |
| <b>Professional Competence</b>                      | <p>After completion of this module, participants will be able to:</p> <ul style="list-style-type: none"> <li>differentiate between different kinds of bioreactors and describe their key features</li> <li>identify and characterize the peripheral and control systems of bioreactors</li> <li>depict integrated biosystems (bioprocesses including up- and downstream processing)</li> <li>name different sterilization methods and evaluate those in terms of different applications</li> <li>recall and define the advanced methods of modern systems-biological approaches</li> <li>connect the multiple "omics"-methods and evaluate their application for biological questions</li> <li>recall the fundamentals of modeling and simulation of biological networks and biotechnological processes and to discuss their methods</li> <li>assess and apply methods and theories of genomics, transcriptomics, proteomics and metabolomics in order to quantify and optimize biological processes at molecular and process levels.</li> </ul> |        |    |
| <i>Knowledge</i>                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |        |    |
| <i>Skills</i>                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |        |    |
| <i>Personal Competence</i>                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |        |    |
| <i>Social Competence</i>                            | <p>After completion of this module, participants will be able to debate technical questions in small teams to enhance the ability to take position to their own opinions and increase their capacity for teamwork.</p> <p>The students can reflect their specific knowledge orally and discuss it with other students and teachers.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |        |    |
| <i>Autonomy</i>                                     | <p>After completion of this module, participants will be able to solve a technical problem in teams of approx. 8-12 persons independently including a presentation of the results.</p> <ul style="list-style-type: none"> <li></li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |        |    |
| <b>Workload in Hours</b>                            | Independent Study Time 110, Study Time in Lecture 70                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |        |    |
| <b>Credit points</b>                                | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |        |    |
| <b>Course achievement</b>                           | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |        |    |
| <b>Examination</b>                                  | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |        |    |
| <b>Examination duration and scale</b>               | 120 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |        |    |
| <b>Assignment for the Following Curricula</b>       | <p>Bioprocess Engineering: Core Qualification: Compulsory</p> <p>Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory</p> <p>Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory</p> <p>Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory</p> <p>International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory</p> <p>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory</p> <p>Process Engineering: Core Qualification: Compulsory</p>                                                                                                                                                                                                                                                                                                                                                                             |        |    |

| Course L1034: Bioreactor Design and Operation |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|-----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                    | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Hrs/wk</b>                                 | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>CP</b>                                     | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Workload in Hours</b>                      | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Lecturer</b>                               | Prof. Anna-Lena Heins                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Language</b>                               | EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Cycle</b>                                  | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Content</b>                                | <p><b>Design of bioreactors and peripheries:</b></p> <ul style="list-style-type: none"> <li>• reactor types and geometry</li> <li>• materials and surface treatment</li> <li>• agitation system design</li> <li>• insertion of stirrer</li> <li>• sealings</li> <li>• fittings and valves</li> <li>• peripherals</li> <li>• materials</li> <li>• standardization</li> <li>• demonstration in laboratory and pilot plant</li> </ul> <p><b>Sterile operation:</b></p> <ul style="list-style-type: none"> <li>• theory of sterilisation processes</li> <li>• different sterilisation methods</li> <li>• sterilisation of reactor and probes</li> <li>• industrial sterile test, automated sterilisation</li> <li>• introduction of biological material</li> <li>• autoclaves</li> <li>• continuous sterilisation of fluids</li> <li>• deep bed filters, tangential flow filters</li> <li>• demonstration and practice in pilot plant</li> </ul> <p><b>Instrumentation and control:</b></p> <ul style="list-style-type: none"> <li>• temperature control and heat exchange</li> <li>• dissolved oxygen control and mass transfer</li> <li>• aeration and mixing</li> <li>• used gassing units and gassing strategies</li> <li>• control of agitation and power input</li> <li>• pH and reactor volume, foaming, membrane gassing</li> </ul> <p><b>Bioreactor selection and scale-up:</b></p> <ul style="list-style-type: none"> <li>• selection criteria</li> <li>• scale-up and scale-down</li> <li>• reactors for mammalian cell culture</li> </ul> <p><b>Integrated biosystem:</b></p> <ul style="list-style-type: none"> <li>• interactions and integration of microorganisms, bioreactor and downstream processing</li> <li>• Miniplant technologies</li> </ul> <p><b>Team work with presentation:</b></p> <ul style="list-style-type: none"> <li>• Operation mode of selected bioprocesses (e.g. fundamentals of batch, fed-batch and continuous cultivation)</li> </ul> |
| <b>Literature</b>                             | <ul style="list-style-type: none"> <li>• Storhas, Winfried, Bioreaktoren und periphere Einrichtungen, Braunschweig: Vieweg, 1994</li> <li>• Chmiel, Horst, Bioprozeßtechnik; Springer 2011</li> <li>• Krahe, Martin, Biochemical Engineering, Ullmann's Encyclopedia of Industrial Chemistry</li> <li>• Pauline M. Doran, Bioprocess Engineering Principles, Second Edition, Academic Press, 2013</li> <li>• Other lecture materials to be distributed</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |



| Course L1037: Bioreactors and Biosystems Engineering |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                           | Project-/problem-based Learning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Hrs/wk</b>                                        | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>CP</b>                                            | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Workload in Hours</b>                             | Independent Study Time 46, Study Time in Lecture 14                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Lecturer</b>                                      | Prof. Anna-Lena Heins                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Language</b>                                      | EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Cycle</b>                                         | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Content</b>                                       | <p><b>Introduction to Biosystems Engineering (Exercise)</b></p> <p><b>Experimental basis and methods for biosystems analysis</b></p> <ul style="list-style-type: none"> <li>• Introduction to genomics, transcriptomics and proteomics</li> <li>• More detailed treatment of metabolomics</li> <li>• Determination of in-vivo kinetics</li> <li>• Techniques for rapid sampling</li> <li>• Quenching and extraction</li> <li>• Analytical methods for determination of metabolite concentrations</li> </ul> <p><b>Analysis, modelling and simulation of biological networks</b></p> <ul style="list-style-type: none"> <li>• Metabolic flux analysis</li> <li>• Introduction</li> <li>• Isotope labelling</li> <li>• Elementary flux modes</li> <li>• Mechanistic and structural network models</li> <li>• Regulatory networks</li> <li>• Systems analysis</li> <li>• Structural network analysis</li> <li>• Linear and non-linear dynamic systems</li> <li>• Sensitivity analysis (metabolic control analysis)</li> </ul> <p><b>Modelling and simulation for bioprocess engineering</b></p> <ul style="list-style-type: none"> <li>• Modelling of bioreactors</li> <li>• Dynamic behaviour of bioprocesses</li> </ul> <p><b>Selected projects for biosystems engineering</b></p> <ul style="list-style-type: none"> <li>• Miniaturisation of bioreaction systems</li> <li>• Miniplant technology for the integration of biosynthesis and downstream processing</li> <li>• Technical and economic overall assessment of bioproduction processes</li> </ul> |
| <b>Literature</b>                                    | <p>E. Klipp et al. Systems Biology in Practice, Wiley-VCH, 2006</p> <p>R. Dohrn: Miniplant-Technik, Wiley-VCH, 2006</p> <p>G.N. Stephanopoulos et. al.: Metabolic Engineering, Academic Press, 1998</p> <p>I.J. Dunn et. al.: Biological Reaction Engineering, Wiley-VCH, 2003</p> <p>Lecture materials to be distributed</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

| Course L1036: Biosystems Engineering |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|--------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                           | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Hrs/wk</b>                        | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>CP</b>                            | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Workload in Hours</b>             | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Lecturer</b>                      | Prof. Johannes Gescher, Prof. Anna-Lena Heins                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Language</b>                      | EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Cycle</b>                         | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Content</b>                       | <p><b>Introduction to Biosystems Engineering</b></p> <p><b>Experimental basis and methods for biosystems analysis</b></p> <ul style="list-style-type: none"> <li>• Introduction to genomics, transcriptomics and proteomics</li> <li>• More detailed treatment of metabolomics</li> <li>• Determination of in-vivo kinetics</li> <li>• Techniques for rapid sampling</li> <li>• Quenching and extraction</li> <li>• Analytical methods for determination of metabolite concentrations</li> </ul> <p><b>Analysis, modelling and simulation of biological networks</b></p> <ul style="list-style-type: none"> <li>• Metabolic flux analysis</li> <li>• Introduction</li> <li>• Isotope labelling</li> <li>• Elementary flux modes</li> <li>• Mechanistic and structural network models</li> <li>• Regulatory networks</li> <li>• Systems analysis</li> <li>• Structural network analysis</li> <li>• Linear and non-linear dynamic systems</li> <li>• Sensitivity analysis (metabolic control analysis)</li> </ul> <p><b>Modelling and simulation for bioprocess engineering</b></p> <ul style="list-style-type: none"> <li>• Modelling of bioreactors</li> <li>• Dynamic behaviour of bioprocesses</li> </ul> <p><b>Selected projects for biosystems engineering</b></p> <ul style="list-style-type: none"> <li>• Miniaturisation of bioreaction systems</li> <li>• Miniplant technology for the integration of biosynthesis and downstream processing</li> <li>• Technical and economic overall assessment of bioproduction processes</li> </ul> |
| <b>Literature</b>                    | <p>E. Klipp et al. Systems Biology in Practice, Wiley-VCH, 2006</p> <p>R. Dohrn: Miniplant-Technik, Wiley-VCH, 2006</p> <p>G.N. Stephanopoulos et. al.: Metabolic Engineering, Academic Press, 1998</p> <p>I.J. Dunn et. al.: Biological Reaction Engineering, Wiley-VCH, 2003</p> <p>Lecture materials to be distributed</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

| Module M1709: Applied Optimization in Energy and Process Engineering |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |              |             |                    |
|----------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|-------------|--------------------|
| Courses                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |              |             |                    |
| Title                                                                | Typ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |              | Hrs/wk      | CP                 |
| Applied optimization in energy and process engineering (L2693)       | Integrated Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |              | 2           | 3                  |
| Applied optimization in energy and process engineering (L2695)       | Recitation Section (small)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |              | 3           | 3                  |
| <b>Module Responsible</b>                                            | Prof. Mirko Skiborowski                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |              |             |                    |
| <b>Admission Requirements</b>                                        | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |              |             |                    |
| <b>Recommended Previous Knowledge</b>                                | <p>Fundamentals in the field of mathematical modeling and numerical mathematics, as well as a basic understanding of process engineering processes.</p> <p>In particular the contents of the module Process and Plant Engineering II</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |              |             |                    |
| <b>Educational Objectives</b>                                        | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |              |             |                    |
| <b>Professional Competence</b><br><i>Knowledge</i>                   | <p>The module provides a general introduction to the basics of applied mathematical optimization and deals with application areas on different scales from the identification of kinetic models, to the optimal design of unit operations and the optimization of entire (sub)processes, as well as production planning. In addition to the basic classification and formulation of optimization problems, different solution approaches are discussed and tested during the exercises. Besides deterministic gradient-based methods, metaheuristics such as evolutionary and genetic algorithms and their application are discussed as well.</p> <ul style="list-style-type: none"> <li>• Introduction to Applied Optimization</li> <li>• Formulation of optimization problems</li> <li>• Linear Optimization</li> <li>• Nonlinear Optimization</li> <li>• Mixed-integer (non)linear optimization</li> <li>• Multi-objective optimization</li> <li>• Global optimization</li> </ul>                                                                                                                                                                                   |              |             |                    |
| <i>Skills</i>                                                        | <p>After successful participation in the module "Applied Optimization in Energy and Process Engineering", students are able to formulate the different types of optimization problems and to select appropriate solution methods in suitable software such as Matlab and GAMS and to develop improved solution strategies. Furthermore, students will be able to interpret and critically examine the results accordingly.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |              |             |                    |
| <b>Personal Competence</b><br><i>Social Competence</i>               | <p>Students are capable of:</p> <ul style="list-style-type: none"> <li>• develop solutions in heterogeneous small groups</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |              |             |                    |
| <i>Autonomy</i>                                                      | <p>Students are capable of:</p> <ul style="list-style-type: none"> <li>• tapping new knowledge on a special subject by literature research</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |              |             |                    |
| <b>Workload in Hours</b>                                             | Independent Study Time 110, Study Time in Lecture 70                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |              |             |                    |
| <b>Credit points</b>                                                 | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |              |             |                    |
| <b>Course achievement</b>                                            | <b>Compulsory</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <b>Bonus</b> | <b>Form</b> | <b>Description</b> |
|                                                                      | No                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 10 %         | Midterm     | Bonuspunkte        |
| <b>Examination</b>                                                   | Oral exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |              |             |                    |
| <b>Examination duration and scale</b>                                | 35 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |              |             |                    |
| <b>Assignment for the Following Curricula</b>                        | <p>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory</p> <p>Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory</p> <p>Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory</p> <p>Computational Methods and Machine Learning in Engineering: Core Qualification: Elective Compulsory</p> <p>Energy Systems: Specialisation Energy Systems: Elective Compulsory</p> <p>Environmental Engineering: Specialisation Energy and Resources: Elective Compulsory</p> <p>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory</p> <p>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory</p> <p>Technomathematics: Specialisation III. Engineering Science: Elective Compulsory</p> <p>Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory</p> <p>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory</p> <p>Process Engineering: Specialisation Process Engineering: Elective Compulsory</p> |              |             |                    |

| Course L2693: Applied optimization in energy and process engineering |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|----------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                           | Integrated Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Hrs/wk</b>                                                        | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>CP</b>                                                            | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Workload in Hours</b>                                             | Independent Study Time 62, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Lecturer</b>                                                      | Prof. Mirko Skiborowski                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Language</b>                                                      | EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Cycle</b>                                                         | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Content</b>                                                       | <p>The lecture offers a general introduction to the basics and possibilities of applied mathematical optimization and deals with application areas on different scales from kinetics identification, optimal design of unit operations to the optimization of entire (sub)processes, and production planning. In addition to the basic classification and formulation of optimization problems, different solution approaches are discussed. Besides deterministic gradient-based methods, metaheuristics such as evolutionary and genetic algorithms and their application are discussed as well.</p> <ul style="list-style-type: none"> <li>- Introduction to Applied Optimization</li> <li>- Formulation of optimization problems</li> <li>- Linear Optimization</li> <li>- Nonlinear Optimization</li> <li>- Mixed-integer (non)linear optimization</li> <li>- Multi-objective optimization</li> <li>- Global optimization</li> </ul> |
| <b>Literature</b>                                                    | <p>Weicker, K., Evolutionäre Algorithmen, Springer, 2015</p> <p>Edgar, T. F., Himmelblau D. M., Lasdon, L. S., Optimization of Chemical Processes, McGraw Hill, 2001</p> <p>Biegler, L. Nonlinear Programming - Concepts, Algorithms, and Applications to Chemical Processes, 2010</p> <p>Kallrath, J. Gemischt-ganzzahlige Optimierung: Modellierung in der Praxis, Vieweg, 2002</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

| Course L2695: Applied optimization in energy and process engineering |                                                     |
|----------------------------------------------------------------------|-----------------------------------------------------|
| <b>Typ</b>                                                           | Recitation Section (small)                          |
| <b>Hrs/wk</b>                                                        | 3                                                   |
| <b>CP</b>                                                            | 3                                                   |
| <b>Workload in Hours</b>                                             | Independent Study Time 48, Study Time in Lecture 42 |
| <b>Lecturer</b>                                                      | Prof. Mirko Skiborowski                             |
| <b>Language</b>                                                      | EN                                                  |
| <b>Cycle</b>                                                         | SoSe                                                |
| <b>Content</b>                                                       | See interlocking course                             |
| <b>Literature</b>                                                    | See interlocking course                             |

| Module M2139: District Heating         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |    |
|----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|----|
| Courses                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |    |
| Title                                  | Typ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Hrs/wk | CP |
| Combined Heat and Power (CHP) (L3430)  | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2      | 2  |
| Pipeline-based Heat Supply (L3428)     | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2      | 2  |
| Heat from Deep Geothermal Heat (L3429) | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2      | 2  |
| Module Responsible                     | Prof. Arne Speerforck                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |        |    |
| Admission Requirements                 | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |        |    |
| Recommended Previous Knowledge         | Technical Thermodynamics I, II, Fluid Dynamics, Heat Transfer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |        |    |
| Educational Objectives                 | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |        |    |
| Professional Competence                | <p>Students are familiar with the technical fundamentals of energy conversion in combined heat and power plants, as well as the conduction-based heat transport and the utilization of deep geothermal energy. They are knowledgeable about the structure and content of relevant technical regulations. They can distinguish between various plant configurations, understand fundamental characteristics, and identify the advantages and disadvantages of different solutions. They are aware of current challenges and can categorize, develop, and evaluate transformation paths for different district heating systems.</p> <p>Students are capable of designing district heating networks and sizing the corresponding plant technology. They can apply calculation methods and technical regulations. They are able to quantify the potential of deep geothermal energy and calculate systems for combined heat and power. They can assess transformation paths for district heating networks and follow public discourse on the heat transition.</p> <p>The students can engage in goal-oriented discussions in small groups using various examples and thought experiments, develop a solution approach, and present it. They are able to independently formulate more in-depth questions within the framework of exercises and work out targeted solutions.</p> <p>Students are able to independently define tasks, develop the necessary knowledge based on the acquired knowledge, and use appropriate tools to implement them. In the exercises, students discuss the methods taught in the lectures using complex problems and critically analyze the results.</p> |        |    |
| Knowledge                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |    |
| Skills                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |    |
| Personal Competence                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |    |
| Social Competence                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |    |
| Autonomy                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |    |
| Workload in Hours                      | Independent Study Time 96, Study Time in Lecture 84                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |        |    |
| Credit points                          | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |        |    |
| Course achievement                     | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |        |    |
| Examination                            | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |        |    |
| Examination duration and scale         | 180 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |        |    |
| Assignment for the Following Curricula | Energy Systems: Specialisation Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |    |

| Course L3430: Combined Heat and Power (CHP) |                                                     |
|---------------------------------------------|-----------------------------------------------------|
| <b>Type</b>                                 | Lecture                                             |
| <b>Hrs/wk</b>                               | 2                                                   |
| <b>CP</b>                                   | 2                                                   |
| <b>Workload in Hours</b>                    | Independent Study Time 32, Study Time in Lecture 28 |
| <b>Lecturer</b>                             | Dr. Kristin Abel-Günther                            |
| <b>Language</b>                             | DE                                                  |
| <b>Cycle</b>                                | SoSe                                                |
| <b>Content</b>                              |                                                     |
| <b>Literature</b>                           |                                                     |

| Course L3428: Pipeline-based Heat Supply |                                                     |
|------------------------------------------|-----------------------------------------------------|
| <b>Type</b>                              | Lecture                                             |
| <b>Hrs/wk</b>                            | 2                                                   |
| <b>CP</b>                                | 2                                                   |
| <b>Workload in Hours</b>                 | Independent Study Time 32, Study Time in Lecture 28 |
| <b>Lecturer</b>                          | NN                                                  |
| <b>Language</b>                          | DE                                                  |
| <b>Cycle</b>                             | SoSe                                                |
| <b>Content</b>                           |                                                     |
| <b>Literature</b>                        |                                                     |

| Course L3429: Heat from Deep Geothermal Heat |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|----------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                   | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Hrs/wk</b>                                | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>CP</b>                                    | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Workload in Hours</b>                     | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Lecturer</b>                              | Dr. Ben Norden                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Language</b>                              | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Cycle</b>                                 | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Content</b>                               | <ol style="list-style-type: none"> <li>1. Geological Background</li> <li>2. Hydrothermal targets for geothermal and aquifer storage applications</li> <li>3. Exploration and petrophysics supporting geothermal planning and site development</li> <li>4. Geological modeling and usage cases</li> </ol>                                                                                                                                                                                                                                                |
| <b>Literature</b>                            | <ul style="list-style-type: none"> <li>• Kaltschmitt et al. (eds): Erneuerbare Energien: Systemtechnik, Wirtschaftlichkeit, Umweltaspekte. Springer, 6. Aufl. 2020.</li> <li>• Livescu, S. &amp; Dindoruk, B (eds): Geothermal Energy Engineering, Elsevier, 2025.</li> <li>• Bloemendal, M. et al., 2014: How to achieve optimal and sustainable use of the subsurface for Aquifer Thermal Energy Storage, Energy Policy, Volume 66, <a href="https://doi.org/10.1016/j.enpol.2013.11.034">https://doi.org/10.1016/j.enpol.2013.11.034</a>.</li> </ul> |

| Module M0900: Examples in Solid Process Engineering                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |                     |                                                       |
|------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|---------------------|-------------------------------------------------------|
| Courses                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |                     |                                                       |
| Title                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Typ                        | Hrs/wk              | CP                                                    |
| Fluidization Technology (L0431)                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Lecture                    | 2                   | 2                                                     |
| Practical Course Fluidization Technology and Drying Technology (L1369) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Practical Course           | 1                   | 1                                                     |
| Drying Technology (L3366)                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Lecture                    | 2                   | 2                                                     |
| Exercises in Fluidization Technology and Drying Technology (L1372)     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Recitation Section (small) | 1                   | 1                                                     |
| Module Responsible                                                     | Prof. Stefan Heinrich                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                            |                     |                                                       |
| Admission Requirements                                                 | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |                     |                                                       |
| Recommended Previous Knowledge                                         | Knowledge from the module particle technology                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                            |                     |                                                       |
| Educational Objectives                                                 | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |                     |                                                       |
| Professional Competence                                                | After completion of the module the students will be able to describe based on examples the assembly of solids engineering processes consisting of multiple apparatuses and subprocesses. They are able to describe the coaction and interrelation of subprocesses.<br><br>Students are able to analyze tasks in the field of solids process engineering and to combine suitable subprocesses in a process chain.<br><br>Students are able to discuss technical problems in a scientific manner.<br><br>Students are able to acquire scientific knowledge independently and discuss technical problems in a scientific manner.                                         |                            |                     |                                                       |
| Knowledge                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |                     |                                                       |
| Skills                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |                     |                                                       |
| Personal Competence                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |                     |                                                       |
| Social Competence                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |                     |                                                       |
| Autonomy                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |                     |                                                       |
| Workload in Hours                                                      | Independent Study Time 96, Study Time in Lecture 84                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                            |                     |                                                       |
| Credit points                                                          | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                            |                     |                                                       |
| Course achievement                                                     | Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Bonus                      | Form                | Description                                           |
|                                                                        | Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | None                       | Written elaboration | drei Berichte (pro Versuch ein Bericht) à 5-10 Seiten |
| Examination                                                            | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                            |                     |                                                       |
| Examination duration and scale                                         | 120 minutes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                            |                     |                                                       |
| Assignment for the Following Curricula                                 | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory<br>Energy Systems: Specialisation Green Energy Technologies: Elective Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |                            |                     |                                                       |

| Course L0431: Fluidization Technology |                                                                                                                                                                                                                                                                                                                                                                                                  |
|---------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Type</b>                           | Lecture                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Hrs/wk</b>                         | 2                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>CP</b>                             | 2                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Workload in Hours</b>              | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                              |
| <b>Lecturer</b>                       | Prof. Stefan Heinrich                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Language</b>                       | EN                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Cycle</b>                          | WiSe                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Content</b>                        | Introduction: definition, fluidization regimes, comparison with other types of gas/solids reactors<br>Typical fluidized bed applications<br>Fluidmechanical principle<br>Local fluid mechanics of gas/solid fluidization<br>Fast fluidization (circulating fluidized bed)<br>Entrainment<br>Solids mixing in fluidized beds<br>Application of fluidized beds to granulation and drying processes |
| <b>Literature</b>                     | Kunii, D.; Levenspiel, O.: Fluidization Engineering. Butterworth Heinemann, Boston, 1991.                                                                                                                                                                                                                                                                                                        |

| Course L1369: Practical Course Fluidization Technology and Drying Technology |                                                                                                                                                                                                                                               |
|------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                                   | Practical Course                                                                                                                                                                                                                              |
| <b>Hrs/wk</b>                                                                | 1                                                                                                                                                                                                                                             |
| <b>CP</b>                                                                    | 1                                                                                                                                                                                                                                             |
| <b>Workload in Hours</b>                                                     | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                           |
| <b>Lecturer</b>                                                              | Prof. Stefan Heinrich                                                                                                                                                                                                                         |
| <b>Language</b>                                                              | EN                                                                                                                                                                                                                                            |
| <b>Cycle</b>                                                                 | WiSe                                                                                                                                                                                                                                          |
| <b>Content</b>                                                               | <p>Experiments:</p> <ul style="list-style-type: none"> <li>• Determination of the minimum fluidization velocity</li> <li>• Heat transfer in fluidized beds</li> <li>• Granulation</li> <li>• Spray drying</li> <li>• Freeze drying</li> </ul> |
| <b>Literature</b>                                                            | Kunii, D.; Levenspiel, O.: Fluidization Engineering. Butterworth Heinemann, Boston, 1991.                                                                                                                                                     |

| Course L3366: Drying Technology |                                                                                                                                                                                                                                                                                                                  |
|---------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                      | Lecture                                                                                                                                                                                                                                                                                                          |
| <b>Hrs/wk</b>                   | 2                                                                                                                                                                                                                                                                                                                |
| <b>CP</b>                       | 2                                                                                                                                                                                                                                                                                                                |
| <b>Workload in Hours</b>        | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                              |
| <b>Lecturer</b>                 | Dr. Swantje Pietsch-Braune                                                                                                                                                                                                                                                                                       |
| <b>Language</b>                 | EN                                                                                                                                                                                                                                                                                                               |
| <b>Cycle</b>                    | WiSe                                                                                                                                                                                                                                                                                                             |
| <b>Content</b>                  | <ul style="list-style-type: none"> <li>• Fundamental knowledge different drying technologies</li> <li>• Understand and calculate heat and mass transfer processes involved in the different drying technologies</li> <li>• Learn about most important types of dryers for industrial applications</li> </ul>     |
| <b>Literature</b>               | <ul style="list-style-type: none"> <li>• Mujumdar, A. S., &amp; Tsotsas, E. (2007). Modern drying technology. Weinheim: Wiley-VCH.</li> <li>• Krischer, O., Kast, W., &amp; Kröll, K. (1978). Die wissenschaftlichen Grundlagen der Trocknungstechnik (3., neubearb. Aufl.). Berlin [u.a.]: Springer.</li> </ul> |

| Course L1372: Exercises in Fluidization Technology and Drying Technology |                                                                                                   |
|--------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                               | Recitation Section (small)                                                                        |
| <b>Hrs/wk</b>                                                            | 1                                                                                                 |
| <b>CP</b>                                                                | 1                                                                                                 |
| <b>Workload in Hours</b>                                                 | Independent Study Time 16, Study Time in Lecture 14                                               |
| <b>Lecturer</b>                                                          | Prof. Stefan Heinrich                                                                             |
| <b>Language</b>                                                          | EN                                                                                                |
| <b>Cycle</b>                                                             | WiSe                                                                                              |
| <b>Content</b>                                                           | Exercises and calculation examples for the lectures Fluidization Technology and Drying Technology |
| <b>Literature</b>                                                        | Kunii, D.; Levenspiel, O.: Fluidization Engineering. Butterworth Heinemann, Boston, 1991.         |



| Module M1909: System Simulation                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |               |           |
|--------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|-----------|
| <b>Courses</b>                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |               |           |
| <b>Title</b>                                                                                                                                     | <b>Typ</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>Hrs/wk</b> | <b>CP</b> |
| System Simulation Modul (L3150)                                                                                                                  | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 3             | 4         |
| System Simulation Modul (L3151)                                                                                                                  | Recitation Section (large)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2             | 2         |
| <b>Module Responsible</b>                                                                                                                        | Prof. Arne Speerforck                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |               |           |
| <b>Admission Requirements</b>                                                                                                                    | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |               |           |
| <b>Recommended Previous Knowledge</b>                                                                                                            | Mathematics I-III, Computer Science, Engineering Thermodynamics I, II, Fluid Dynamics, Heat Transfer, Control Systems                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |               |           |
| <b>Educational Objectives</b>                                                                                                                    | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |               |           |
| <b>Professional Competence</b><br><i>Knowledge</i><br><i>Skills</i><br><b>Personal Competence</b><br><i>Social Competence</i><br><i>Autonomy</i> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |               |           |
| <b>Workload in Hours</b>                                                                                                                         | Independent Study Time 110, Study Time in Lecture 70                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |               |           |
| <b>Credit points</b>                                                                                                                             | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |               |           |
| <b>Course achievement</b>                                                                                                                        | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |               |           |
| <b>Examination</b>                                                                                                                               | Oral exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |               |           |
| <b>Examination duration and scale</b>                                                                                                            | 30 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |               |           |
| <b>Assignment for the Following Curricula</b>                                                                                                    | Energy Systems: Specialisation Energy Systems: Compulsory<br>Energy Systems: Specialisation Green Energy Technologies: Elective Compulsory<br>Aircraft Systems Engineering: Core Qualification: Elective Compulsory<br>Aeronautics: Core Qualification: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Specialisation Product Development: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Specialisation Production: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Specialisation Materials: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Production: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Materials: Elective Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory |               |           |

| Course L3150: System Simulation Modul |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                            | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Hrs/wk</b>                         | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>CP</b>                             | 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Workload in Hours</b>              | Independent Study Time 78, Study Time in Lecture 42                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Lecturer</b>                       | Prof. Arne Speerforck, Dr. Johannes Brunnemann                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Language</b>                       | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Cycle</b>                          | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Content</b>                        | <p>Lecture about equation-based, physical modelling using the modelling language Modelica and the free simulation tool OpenModelica 1.17.0.</p> <ul style="list-style-type: none"> <li>• Instruction and modelling of physical processes</li> <li>• Modelling and limits of model</li> <li>• Time constant, stiffness, stability, step size</li> <li>• Terms of object orientated programming</li> <li>• Differential equations of simple systems</li> <li>• Introduction into Modelica</li> <li>• Introduction into simulation tool</li> <li>• Example:Hydraulic systems and heat transfer</li> <li>• Example: System with different subsystems</li> </ul>                                                                                                                                                                                     |
| <b>Literature</b>                     | <p>[1] Modelica Association: "Modelica Language Specification - Version 3.5", Linköping, Sweden, 2021.</p> <p>[2] OpenModelica: OpenModelica 1.17.0, <a href="https://www.openmodelica.org">https://www.openmodelica.org</a> (siehe Download), 2021.</p> <p>[3] M. Tiller: "Modelica by Example", <a href="https://book.xogeny.com">https://book.xogeny.com</a>, 2014.</p> <p>[4] M. Otter, H. Elmqvist, et al.: "Objektorientierte Modellierung Physikalischer Systeme", at- Automatisierungstechnik (german), Teil 1 - 17, Oldenbourg Verlag, 1999 - 2000.</p> <p>[5] P. Fritzson: "Principles of Object-Oriented Modeling and Simulation with Modelica 3.3", Wiley-IEEE Press, New York, 2015.</p> <p>[6] P. Fritzson: "Introduction to Modeling and Simulation of Technical and Physical Systems with Modelica", Wiley, New York, 2011.</p> |

| Course L3151: System Simulation Modul |                                                     |
|---------------------------------------|-----------------------------------------------------|
| <b>Typ</b>                            | Recitation Section (large)                          |
| <b>Hrs/wk</b>                         | 2                                                   |
| <b>CP</b>                             | 2                                                   |
| <b>Workload in Hours</b>              | Independent Study Time 32, Study Time in Lecture 28 |
| <b>Lecturer</b>                       | Prof. Arne Speerforck, Dr. Johannes Brunnemann      |
| <b>Language</b>                       | DE                                                  |
| <b>Cycle</b>                          | WiSe                                                |
| <b>Content</b>                        | See interlocking course                             |
| <b>Literature</b>                     | See interlocking course                             |

| Module M2006: Waste Treatment and Recycling                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                 |        |    |
|------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|--------|----|
| Courses                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                 |        |    |
| Title                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Type                            | Hrs/wk | CP |
| Planning of waste treatment plants (L3267)                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Project-/problem-based Learning | 3      | 3  |
| Recycling technologies and thermal waste treatment (L3265) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Lecture                         | 2      | 2  |
| Recycling technologies and thermal waste treatment (L3266) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Recitation Section (small)      | 1      | 1  |
| Module Responsible                                         | Prof. Kerstin Kuchta                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                 |        |    |
| Admission Requirements                                     | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                 |        |    |
| Recommended Previous Knowledge                             | <ul style="list-style-type: none"><li>Basics of thermo dynamics</li><li>Basics of fluid dynamics</li><li>fluid dynamics chemistry</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                 |        |    |
| Educational Objectives                                     | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                 |        |    |
| Professional Competence                                    | <p><i>Knowledge</i> The students can name, describe current issue and problems in the field of waste treatment (mechanical, chemical and thermal) and contemplate them in the context of their field.</p> <p>The industrial application of unit operations as part of process engineering is explained by actual examples of waste technologies . Compostion, particle sizes, transportation and dosing of wastes are described as important unit operations .</p> <p>Students will be able to design and design waste treatment technology equipment.</p> <p><i>Skills</i> The students are able to select suitable processes for the treatment of wastes or raw material with respect to their characteristics and the process aims. They can evaluate the efforts and costs for processes and select economically feasible treatment concepts.</p> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> Students can</p> <ul style="list-style-type: none"><li>respectfully work together as a team and discuss technical tasks</li><li>participate in subject-specific and interdisciplinary discussions,</li><li>develop cooperated solutions</li><li>promote the scientific development and accept professional constructive criticism.</li></ul> <p><i>Autonomy</i> Students can independently tap knowledge of the subject area and transform it to new questions. They are capable, in consultation with supervisors, to assess their learning level and define further steps on this basis. Furthermore, they can define targets for new application-or research-oriented duties in accordance with the potential social, economic and cultural impact.</p> |                                 |        |    |
| Workload in Hours                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                 |        |    |
| Credit points                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                 |        |    |
| Course achievement                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                 |        |    |
| Examination                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                 |        |    |
| Examination duration and scale                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                 |        |    |
| Assignment for the Following Curricula                     | Civil Engineering: Specialisation Water and Traffic: Elective Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory<br>Energy Systems: Specialisation Green Energy Technologies: Elective Compulsory<br>Environmental Engineering: Specialisation Energy and Resources: Elective Compulsory<br>International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Compulsory<br>Water and Environmental Engineering: Specialisation Cities: Elective Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                 |        |    |

| Course L3267: Planning of waste treatment plants |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|--------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                       | Project-/problem-based Learning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Hrs/wk</b>                                    | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>CP</b>                                        | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Workload in Hours</b>                         | Independent Study Time 48, Study Time in Lecture 42                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Lecturer</b>                                  | Prof. Rüdiger Siechau                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Language</b>                                  | EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Cycle</b>                                     | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Content</b>                                   | <p>The focus is on getting to know the organization and practice of waste management companies. Topics such as planning, financing and logistics will be discussed and there will be an excursion (waste incineration plant, vehicle fleet and collection systems / containers).</p> <p>Project based learning: You will be given a task to work on independently in groups of 4 to 6 students. All tools and data needed for the project work will be discussed in the lecture "Recycling Technologies and Thermal Waste Treatment". Course documents can be downloaded from StudIP. Communication during the project work also takes place via StudIP.</p> |
| <b>Literature</b>                                | <ul style="list-style-type: none"> <li>Einführung in die Abfallwirtschaft; Martin Kranert, Klaus Cord-Landwehr (Hrsg.); Vieweg + Teubner Verlag; 2010</li> <li>PowerPoint Präsentationen in Stud IP</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                               |

| Course L3265: Recycling technologies and thermal waste treatment |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                       | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Hrs/wk</b>                                                    | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>CP</b>                                                        | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Workload in Hours</b>                                         | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Lecturer</b>                                                  | Prof. Kerstin Kuchta                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Language</b>                                                  | EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Cycle</b>                                                     | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Content</b>                                                   | <ul style="list-style-type: none"> <li>Introduction, actual state-of-the-art of waste incineration, aims. legal background, reaction principals</li> <li>basics of incineration processes: waste composition, calorific value, calculation of air demand and flue gas composition</li> <li>Incineration techniques: grate firing, ash transfer, boiler</li> <li>Flue gas cleaning: Volume, composition, legal frame work and emission limits, dry treatment, scrubber, de-nox techniques, dioxin elimination, Mercury elimination</li> <li>Ash treatment: Mass, quality, treatment concepts, recycling, disposal</li> </ul> |
| <b>Literature</b>                                                | Thomé-Kozmiensky, K. J. (Hrsg.): Thermische Abfallbehandlung Bande 1-7. EF-Verlag für Energie- und Umwelttechnik, Berlin, 196 - 2013.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

| Course L3266: Recycling technologies and thermal waste treatment |                                                     |
|------------------------------------------------------------------|-----------------------------------------------------|
| <b>Typ</b>                                                       | Recitation Section (small)                          |
| <b>Hrs/wk</b>                                                    | 1                                                   |
| <b>CP</b>                                                        | 1                                                   |
| <b>Workload in Hours</b>                                         | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>                                                  | Prof. Kerstin Kuchta                                |
| <b>Language</b>                                                  | EN                                                  |
| <b>Cycle</b>                                                     | WiSe                                                |
| <b>Content</b>                                                   | See interlocking course                             |
| <b>Literature</b>                                                | See interlocking course                             |

| Module M1354: Advanced Fuels                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
|--------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|-------------------------------------------------------------|
| Courses                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
| Title                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Type                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Hrs/wk              | CP                                                          |
| Second generation biofuels and electricity based fuels (L2414)           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2                   | 2                                                           |
| Carbon dioxide as an economic determinant in the mobility sector (L1926) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1                   | 1                                                           |
| Mobility and climate protection (L2416)                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Recitation Section (small)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 2                   | 2                                                           |
| Sustainability aspects and regulatory framework (L2415)                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1                   | 1                                                           |
| Module Responsible                                                       | Dr. Marvin Scherzinger                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
| Admission Requirements                                                   | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
| Recommended Previous Knowledge                                           | Bachelor degree in Process Engineering, Bioprocess Engineering or Energy- and Environmental Engineering                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
| Educational Objectives                                                   | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
| <b>Professional Competence</b>                                           | <i>Knowledge</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Within the module, students learn about different provision pathways for the production of advanced fuels (biofuels like e.g. alcohol-to-jet; electricity-based fuels like e.g. power-to-liquid). The different processes chains are explained and the regulatory framework for sustainable fuel production is examined. This includes, for example, the requirements of the Renewable Energies Directive II and the conditions and aspects for a market ramp-up of these fuels. For the holistic assessment of the various fuel options, they are also examined under environmental and economic factors.                                                                      |                     |                                                             |
|                                                                          | <i>Skills</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | After successfully participating, the students are able to solve simulation and application tasks of renewable energy technology: <ul style="list-style-type: none"><li>• Module-spanning solutions for the design and presentation of fuel production processes resp. the fuel provision chains</li><li>• Comprehensive analysis of various fuel production options in technical, ecological and economic terms</li></ul> Through active discussions of the various topics within the lectures and exercises of the module, the students improve their understanding and application of the theoretical foundations and are thus able to transfer the learned to the practice. |                     |                                                             |
|                                                                          | <b>Personal Competence</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
|                                                                          | <i>Social Competence</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | The students can discuss scientific tasks in a subject-specific and interdisciplinary way and develop joint solutions.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                     |                                                             |
|                                                                          | <i>Autonomy</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | The students are able to access independent sources about the questions to be addressed and to acquire the necessary knowledge. They are able to assess their respective learning situation concretely in consultation with their supervisor and to define further questions and solutions.                                                                                                                                                                                                                                                                                                                                                                                     |                     |                                                             |
| Workload in Hours                                                        | Independent Study Time 96, Study Time in Lecture 84                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
| Credit points                                                            | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
| Course achievement                                                       | Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Bonus                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Form                | Description                                                 |
|                                                                          | Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 20 %                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Written elaboration | Details werden in der ersten Veranstaltung bekannt gegeben. |
| Examination                                                              | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
| Examination duration and scale                                           | 120 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
| Assignment for the Following Curricula                                   | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory<br>Environmental Engineering: Specialisation Energy and Resources: Elective Compulsory<br>Aircraft Systems Engineering: Core Qualification: Elective Compulsory<br>Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory<br>Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory<br>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |

| Course L2414: Second generation biofuels and electricity based fuels |                                                                                                                                                                                                                                                                                                |
|----------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                           | Lecture                                                                                                                                                                                                                                                                                        |
| <b>Hrs/wk</b>                                                        | 2                                                                                                                                                                                                                                                                                              |
| <b>CP</b>                                                            | 2                                                                                                                                                                                                                                                                                              |
| <b>Workload in Hours</b>                                             | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                            |
| <b>Lecturer</b>                                                      | Dr. Marvin Scherzinger                                                                                                                                                                                                                                                                         |
| <b>Language</b>                                                      | DE/EN                                                                                                                                                                                                                                                                                          |
| <b>Cycle</b>                                                         | WiSe                                                                                                                                                                                                                                                                                           |
| <b>Content</b>                                                       | <ul style="list-style-type: none"> <li>General overview of various power-based fuels and their process paths, including power-to-liquid process (Fischer-Tropsch synthesis, methanol synthesis), power-to-gas (Sabatier process)</li> <li>Origin, production and use of these fuels</li> </ul> |
| <b>Literature</b>                                                    | <ul style="list-style-type: none"> <li>Vorlesungsskript</li> </ul>                                                                                                                                                                                                                             |

| Course L1926: Carbon dioxide as an economic determinant in the mobility sector |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|--------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                                     | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Hrs/wk</b>                                                                  | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>CP</b>                                                                      | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Workload in Hours</b>                                                       | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Lecturer</b>                                                                | Dr. Karsten Wilbrand                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Language</b>                                                                | DE/EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Cycle</b>                                                                   | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Content</b>                                                                 | <ul style="list-style-type: none"> <li>General overview of various advanced biofuels and their process pathways (including gas-to-liquid, HEFA and Alcohol-to-Jet processes)</li> <li>Origin, production and use of these fuels</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Literature</b>                                                              | <ul style="list-style-type: none"> <li>Babu, V.: Biofuels Production. Beverly, Mass: Scrivener [u.a.], 2013</li> <li>Olsson, L.: Biofuels. Berlin, Heidelberg: Springer-Verlag Berlin Heidelberg, 2007</li> <li>William, L. L.: Distillation Design and Control Using Aspen Simulation; ISBN-10: 0-471-77888-5</li> <li>Perry, R.; Green, R.: Perry's Chemical Engineers' Handbook, 8th Edition, McGraw Hill Professional, 20</li> <li>Sinnott, R. K.: Chemical Engineering Design, Elsevier, 2014</li> <li>Kaltschmitt, M.; Neuling, U. (Ed.): Biokerosene - Status and Prospects; Springer, Berlin, Heidelberg, 2018</li> </ul> |

| Course L2416: Mobility and climate protection |                                                                                                                                                                                                                                                                                                                                                                                                        |
|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                    | Recitation Section (small)                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Hrs/wk</b>                                 | 2                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>CP</b>                                     | 2                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Workload in Hours</b>                      | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                    |
| <b>Lecturer</b>                               | Dr. Benedikt Buchspies, Dr. Karsten Wilbrand                                                                                                                                                                                                                                                                                                                                                           |
| <b>Language</b>                               | DE/EN                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Cycle</b>                                  | WiSe                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Content</b>                                | <p>Application of the acquired theoretical knowledge from the respective lectures on the basis of concrete tasks from practice</p> <ul style="list-style-type: none"> <li>Design and simulation of sub-processes of production processes in Aspen Plus ®</li> <li>Ecological and economic analysis of fuel supply paths</li> <li>Classification of case studies into applicable regulations</li> </ul> |
| <b>Literature</b>                             | <ul style="list-style-type: none"> <li>Skriptum zur Vorlesung</li> <li>Aspen Plus® - Aspen Plus User Guide</li> </ul>                                                                                                                                                                                                                                                                                  |

| Course L2415: Sustainability aspects and regulatory framework |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|---------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                    | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Hrs/wk</b>                                                 | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>CP</b>                                                     | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Workload in Hours</b>                                      | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Lecturer</b>                                               | Dr. Benedikt Buchspies                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Language</b>                                               | DE/EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Cycle</b>                                                  | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Content</b>                                                | <p>Holistic examination of the different fuel paths with the following main topics, among others:</p> <ul style="list-style-type: none"> <li>• Consideration of the environmental impact of the various alternative fuels</li> <li>• Economic consideration of the different alternative fuels</li> <li>• Regulatory framework for alternative fuels</li> <li>• Certification of alternative fuels</li> <li>• Market introduction models of alternative fuels</li> </ul>                      |
| <b>Literature</b>                                             | <ul style="list-style-type: none"> <li>• European Commission - Joint Research Center (2010): International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed guidance. Joint Research Center (JRC) Institut for Environment and Sustainability, Luxembourg</li> <li>• Richtlinie (EU) 2018/2001 des Europäischen Parlaments und des Rates vom 11. Dezember 2018 zur Förderung der Nutzung von Energie aus erneuerbaren Quellen</li> </ul> |

| Module M2158: Data Science for Energy System Modelling |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |               |           |
|--------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|-----------|
| <b>Courses</b>                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |               |           |
| <b>Title</b>                                           | <b>Typ</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <b>Hrs/wk</b> | <b>CP</b> |
| Data Science for Energy System Modelling (L3460)       | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 4             | 6         |
| <b>Module Responsible</b>                              | Dozenten des SD V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |               |           |
| <b>Admission Requirements</b>                          | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |               |           |
| <b>Recommended Previous Knowledge</b>                  | Electrical Power Systems II: Operation and Information Systems of Electrical Power Grids / Dimensioning and Assessment of Renewable Energy Systems / Sustainable energy from wind and water / System simulation / Applied optimization in energy and process engineering                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |               |           |
| <b>Educational Objectives</b>                          | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |               |           |
| <b>Professional Competence</b>                         | <p><i>Knowledge</i> The module provides a general introduction to data-driven energy system modelling and covers the geographical and socio-economic potentials of renewable energy sources, their integration into existing energy systems, as well as the technical and economic analysis of storage and grid infrastructure. By working with real-world datasets, students learn how to collect, process, and interpret large amounts of data to support model-based decisions. In addition to essential mathematical optimization methods, the course offers hands-on experience with common open-source software tools and programming frameworks.</p> <p>The following topics are covered, among others:</p> <ul style="list-style-type: none"> <li>• Time series analysis of renewable energy sources (wind, solar) and energy demand</li> <li>• GIS-based assessment of renewable energy potentials</li> <li>• Modelling of energy storage and transmission networks</li> <li>• Fundamentals (and revision) of mathematical optimization</li> <li>• Electricity market design and system planning (e.g., merit order, market values, redispatch, nodal pricing)</li> <li>• Sector coupling and demand-side management</li> <li>• Uncertainty analysis and complexity-reduction methods</li> <li>• Implementation of energy system models in Python (e.g., pandas, geopandas, pyomo, cartopy, rasterio, PyPSA, atlite)</li> <li>• Visualization and communication of modelling results</li> </ul> <p><i>Skills</i> After successful participation in the module "Data Science for Energy System Modelling", students will be able to formulate different types of data-driven and energy-economic modelling and optimization problems. They can select and apply appropriate methods and tools (e.g., Python, Jupyter Notebooks, PyPSA, GAMS or comparable frameworks). Moreover, they are capable of independently developing strategies for model validation and for solving complex tasks, as well as interpreting and critically evaluating the obtained results.</p> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> Students are capable of:</p> <ul style="list-style-type: none"> <li>• developing solution strategies to complex energy system modelling problems in heterogeneous small groups,</li> <li>• giving and receiving constructive feedback in project teams and preparing joint results,</li> <li>• engaging in professional discussions and presenting results in a structured manner.</li> </ul> <p><i>Autonomy</i> Students are capable of:</p> <ul style="list-style-type: none"> <li>• independently acquiring new knowledge through relevant literature and open-source documentation,</li> <li>• identifying open questions and addressing them using suitable methods,</li> <li>• reflecting on results and solution approaches to make them applicable to future tasks.</li> </ul> |               |           |
| <b>Workload in Hours</b>                               | Independent Study Time 124, Study Time in Lecture 56                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |               |           |
| <b>Credit points</b>                                   | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |               |           |
| <b>Course achievement</b>                              | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |               |           |
| <b>Examination</b>                                     | Written elaboration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |               |           |
| <b>Examination duration and scale</b>                  | 10 pages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |               |           |
| <b>Assignment for the Following Curricula</b>          | Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |               |           |

| Course L3460: Data Science for Energy System Modelling |                                                      |
|--------------------------------------------------------|------------------------------------------------------|
| <b>Typ</b>                                             | Lecture                                              |
| <b>Hrs/wk</b>                                          | 4                                                    |
| <b>CP</b>                                              | 6                                                    |
| <b>Workload in Hours</b>                               | Independent Study Time 124, Study Time in Lecture 56 |
| <b>Lecturer</b>                                        | NN                                                   |
| <b>Language</b>                                        | EN                                                   |
| <b>Cycle</b>                                           | WiSe                                                 |
| <b>Content</b>                                         |                                                      |
| <b>Literature</b>                                      |                                                      |



## Specialization Solar Energy Systems

Within the specialization "Solar Energy Systems" further knowledge is gained in the theoretical functioning of photovoltaic cells and the properties of used materials. In addition, further information on the design, management and optimization of electrical energy systems are part in this specialization in order to demonstrate and evaluate the challenges of using solar energy systems in existing networks.

Within the specialization "Solar Energy Systems", students have been given the opportunity to study abroad at the "University of Jordan" in Amman, Jordan. Within this foreign stay, additional modules in the field of "solar energy systems" can be chosen. The earned ECTS are recognized at TUHH by agreement.

In addition, students in the "Solar Energy Systems" course can take the module "Modeling and Simulation of Building Integrated Solar Energy Systems" in cooperation with the International Hellenic University in Thessaloniki, Greece, which can be recognized by TUHH. The Exchange is also encouraged.

**Students, who are planning to choose the specialization "Solar Energy Systems" are kindly requested to contact the head of the program early for further information about the course of studies and their stay abroad.**

| Module M0643: Optoelectronics I - Wave Optics                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |        |    |
|-----------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|--------|----|
| Courses                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |        |    |
| Title                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Typ                        | Hrs/wk | CP |
| Optoelectronics I: Wave Optics (L0359)                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Lecture                    | 2      | 3  |
| Optoelectronics I: Wave Optics (Problem Solving Course) (L0361) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Recitation Section (small) | 1      | 1  |
| Module Responsible                                              | Prof. Alexander Petrov                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                            |        |    |
| Admission Requirements                                          | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                            |        |    |
| Recommended Previous Knowledge                                  | Basics in electrodynamics, calculus                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                            |        |    |
| Educational Objectives                                          | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                            |        |    |
| Professional Competence                                         | <p><i>Knowledge</i> Students can explain the fundamental mathematical and physical relations of freely propagating optical waves. They can give an overview on wave optical phenomena such as diffraction, reflection and refraction, etc. Students can describe waveoptics based components such as electrooptical modulators in an application oriented way.</p> <p><i>Skills</i> Students can generate models and derive mathematical descriptions in relation to free optical wave propagation. They can derive approximative solutions and judge factors influential on the components' performance.</p> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> Students can jointly solve subject related problems in groups. They can present their results effectively within the framework of the problem solving course.</p> <p><i>Autonomy</i> Students are capable to extract relevant information from the provided references and to relate this information to the content of the lecture. They can reflect their acquired level of expertise with the help of lecture accompanying measures such as exam typical exam questions. Students are able to connect their knowledge with that acquired from other lectures.</p> |                            |        |    |
|                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |        |    |
|                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |        |    |
|                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |        |    |
| Workload in Hours                                               | Independent Study Time 78, Study Time in Lecture 42                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                            |        |    |
| Credit points                                                   | 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                            |        |    |
| Course achievement                                              | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                            |        |    |
| Examination                                                     | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                            |        |    |
| Examination duration and scale                                  | 60 minutes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |        |    |
| Assignment for the Following Curricula                          | Electrical Engineering and Information Technology: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory<br>Electrical Engineering and Information Technology: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory<br>Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory<br>Materials Science and Engineering: Specialisation Nano and Hybrid Materials: Elective Compulsory<br>Microelectronics and Microsystems: Specialisation Microelectronics Complements: Elective Compulsory<br>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                            |        |    |

| Course L0359: Optoelectronics I: Wave Optics |                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                   | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Hrs/wk</b>                                | 2                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>CP</b>                                    | 3                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Workload in Hours</b>                     | Independent Study Time 62, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Lecturer</b>                              | Prof. Alexander Petrov                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Language</b>                              | EN                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Cycle</b>                                 | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Content</b>                               | <ul style="list-style-type: none"> <li>• Introduction to optics</li> <li>• Electromagnetic theory of light</li> <li>• Interference</li> <li>• Coherence</li> <li>• Diffraction</li> <li>• Fourier optics</li> <li>• Polarisation and Crystal optics</li> <li>• Matrix formalism</li> <li>• Reflection and transmission</li> <li>• Complex refractive index</li> <li>• Dispersion</li> <li>• Modulation and switching of light</li> </ul> |
| <b>Literature</b>                            | Bahaa E. A. Saleh, Malvin Carl Teich, Fundamentals of Photonics, Wiley 2007<br>Hecht, E., Optics, Benjamin Cummings, 2001<br>Goodman, J.W. Statistical Optics, Wiley, 2000<br>Lauterborn, W., Kurz, T., Coherent Optics: Fundamentals and Applications, Springer, 2002                                                                                                                                                                   |

| Course L0361: Optoelectronics I: Wave Optics (Problem Solving Course) |                                                     |
|-----------------------------------------------------------------------|-----------------------------------------------------|
| <b>Typ</b>                                                            | Recitation Section (small)                          |
| <b>Hrs/wk</b>                                                         | 1                                                   |
| <b>CP</b>                                                             | 1                                                   |
| <b>Workload in Hours</b>                                              | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>                                                       | Prof. Alexander Petrov                              |
| <b>Language</b>                                                       | EN                                                  |
| <b>Cycle</b>                                                          | SoSe                                                |
| <b>Content</b>                                                        | see lecture Optoelectronics 1 - Wave Optics         |
| <b>Literature</b>                                                     | see lecture Optoelectronics 1 - Wave Optics         |

| Module M0932: Process Measurement Engineering |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |        |    |
|-----------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|--------|----|
| Courses                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |        |    |
| Title                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Type                       | Hrs/wk | CP |
| Process Measurement Engineering (L1077)       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Lecture                    | 2      | 3  |
| Process Measurement Engineering (L1083)       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Recitation Section (large) | 1      | 1  |
| <b>Module Responsible</b>                     | Prof. Roland Harig                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                            |        |    |
| <b>Admission Requirements</b>                 | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                            |        |    |
| <b>Recommended Previous Knowledge</b>         | Fundamental principles of electrical engineering and measurement technology                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                            |        |    |
| <b>Educational Objectives</b>                 | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                            |        |    |
| <b>Professional Competence</b>                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |        |    |
| <i>Knowledge</i>                              | The students possess an understanding of complex, state-of-the-art process measurement equipment. They can relate devices and procedures to a variety of commonly used measurement and communications technology.                                                                                                                                                                                                                                                                                                                                                |                            |        |    |
| <i>Skills</i>                                 | The students are capable of modeling and evaluating complex systems of sensing devices as well as associated communications systems. An emphasis is placed on a system-oriented understanding of the measurement equipment.                                                                                                                                                                                                                                                                                                                                      |                            |        |    |
| <b>Personal Competence</b>                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |        |    |
| <i>Social Competence</i>                      | Students can communicate the discussed technologies using the English language.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |        |    |
| <i>Autonomy</i>                               | Students are capable of gathering necessary information from provided references and relate this information to the lecture. They are able to continually reflect their knowledge by means of activities that accompany the lecture. Based on respective feedback, students are expected to adjust their individual learning process. They are able to draw connections between their knowledge obtained in this lecture and the content of other lectures (e.g. Fundamentals of Electrical Engineering, Analysis, Stochastic Processes, Communication Systems). |                            |        |    |
| <b>Workload in Hours</b>                      | Independent Study Time 78, Study Time in Lecture 42                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                            |        |    |
| <b>Credit points</b>                          | 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                            |        |    |
| <b>Course achievement</b>                     | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                            |        |    |
| <b>Examination</b>                            | Oral exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                            |        |    |
| <b>Examination duration and scale</b>         | 45 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                            |        |    |
| <b>Assignment for the Following Curricula</b> | Electrical Engineering and Information Technology: Specialisation Control and Power Systems Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory<br>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory                                                                                                                                                                                                                                                |                            |        |    |

| Course L1077: Process Measurement Engineering |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|-----------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                    | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Hrs/wk</b>                                 | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>CP</b>                                     | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Workload in Hours</b>                      | Independent Study Time 62, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Lecturer</b>                               | Prof. Roland Harig                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Language</b>                               | DE/EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Cycle</b>                                  | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Content</b>                                | <ul style="list-style-type: none"> <li>• Introduction to Process Measurement Engineering</li> <li>• Fundamentals <ul style="list-style-type: none"> <li>◦ Characteristics, Statistics, Calibration</li> <li>◦ Fourier Transform, Convolution, Cross Correlation, Sampling Theorem</li> </ul> </li> <li>• Sensors <ul style="list-style-type: none"> <li>◦ Distance, Pressure, Strain</li> <li>◦ Temperature, Infrared</li> </ul> </li> <li>• Amplification</li> <li>• Analog to Digital Conversion</li> <li>• Data Transmission and Data Systems</li> <li>• Example: Advanced Process Measurement Systems based on Optical Spectroscopy</li> </ul>                                                                                    |
| <b>Literature</b>                             | <p>- Färber: „Prozeßrechentchnik“, Springer-Verlag 1994</p> <p>- Kiencke, Kronmüller: „Meßtechnik“, Springer Verlag Berlin Heidelberg, 1995</p> <p>- A. Ambardar: „Analog and Digital Signal Processing“ (1), PWS Publishing Company, 1995, NTC 339</p> <p>- A. Papoulis: „Signal Analysis“ (1), McGraw-Hill, 1987, NTC 312 (LB)</p> <p>- M. Schwartz: „Information Transmission, Modulation and Noise“ (3,4), McGraw-Hill, 1980, 2402095</p> <p>- S. Haykin: „Communication Systems“ (1,3), Wiley&amp;Sons, 1983, 2419072</p> <p>- H. Sheingold: „Analog-Digital Conversion Handbook“ (5), Prentice-Hall, 1986, 2440072</p> <p>- J. Fraden: „AIP Handbook of Modern Sensors“ (5,6), American Institute of Physics, 1993, MTB 346</p> |

| Course L1083: Process Measurement Engineering |                                                     |
|-----------------------------------------------|-----------------------------------------------------|
| <b>Typ</b>                                    | Recitation Section (large)                          |
| <b>Hrs/wk</b>                                 | 1                                                   |
| <b>CP</b>                                     | 1                                                   |
| <b>Workload in Hours</b>                      | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>                               | Prof. Roland Harig                                  |
| <b>Language</b>                               | DE/EN                                               |
| <b>Cycle</b>                                  | SoSe                                                |
| <b>Content</b>                                | See interlocking course                             |
| <b>Literature</b>                             | See interlocking course                             |

| Module M1343: Structure and properties of fibre-polymer-composites |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                 |        |    |
|--------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|--------|----|
| Courses                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                 |        |    |
| Title                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Type                            | Hrs/wk | CP |
| Structure and properties of fibre-polymer-composites (L1894)       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Lecture                         | 2      | 3  |
| Structure and properties of fibre-polymer-composites (L2614)       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Project-/problem-based Learning | 2      | 2  |
| Structure and properties of fibre-polymer-composites (L2613)       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Recitation Section (large)      | 1      | 1  |
| Module Responsible                                                 | Prof. Bodo Fiedler                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                 |        |    |
| Admission Requirements                                             | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                 |        |    |
| Recommended Previous Knowledge                                     | Basics: chemistry / physics / materials science                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                 |        |    |
| Educational Objectives                                             | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                 |        |    |
| <b>Professional Competence</b><br><i>Knowledge</i>                 | Students can use the knowledge of fiber-reinforced composites (FRP) and its constituents to play (fiber / matrix) and define the necessary testing and analysis.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                 |        |    |
|                                                                    | They can explain the complex relationships structure-property relationship and                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                 |        |    |
|                                                                    | the interactions of chemical structure of the polymers, their processing with the different fiber types, including to explain neighboring contexts (e.g. sustainability, environmental protection).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                 |        |    |
| <i>Skills</i>                                                      | Students are capable of                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                 |        |    |
|                                                                    | <ul style="list-style-type: none"><li>• using standardized calculation methods in a given context to mechanical properties (modulus, strength) to calculate and evaluate the different materials.</li><li>• approximate sizing using the network theory of the structural elements implement and evaluate.</li><li>• selecting appropriate solutions for mechanical recycling problems and sizing example stiffness, corrosion resistance.</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                 |        |    |
| <b>Personal Competence</b><br><i>Social Competence</i>             | Students can                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                 |        |    |
|                                                                    | <ul style="list-style-type: none"><li>• arrive at funded work results in heterogenius groups and document them.</li><li>• provide appropriate feedback and handle feedback on their own performance constructively.</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                 |        |    |
| <i>Autonomy</i>                                                    | Students are able to                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                 |        |    |
|                                                                    | <ul style="list-style-type: none"><li>- assess their own strengths and weaknesses.</li><li>- assess their own state of learning in specific terms and to define further work steps on this basis.</li><li>- assess possible consequences of their professional activity.</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                 |        |    |
| Workload in Hours                                                  | Independent Study Time 110, Study Time in Lecture 70                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                 |        |    |
| Credit points                                                      | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                 |        |    |
| Course achievement                                                 | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                 |        |    |
| Examination                                                        | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                 |        |    |
| Examination duration and scale                                     | 90 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                 |        |    |
| Assignment for the Following Curricula                             | Aircraft Systems Engineering: Core Qualification: Elective Compulsory<br>International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory<br>Aeronautics: Core Qualification: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Specialisation Product Development: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Specialisation Production: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Specialisation Materials: Compulsory<br>Materials Science and Engineering: Specialisation Engineering Materials: Elective Compulsory<br>Mechanical Engineering and Management: Core Qualification: Compulsory<br>Biomedical Engineering: Specialisation Implants and Endoprotheses: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Production: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Materials: Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Materials Science: Elective Compulsory |                                 |        |    |

| Course L1894: Structure and properties of fibre-polymer-composites |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|--------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                         | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Hrs/wk</b>                                                      | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>CP</b>                                                          | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Workload in Hours</b>                                           | Independent Study Time 62, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Lecturer</b>                                                    | Prof. Bodo Fiedler                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Language</b>                                                    | EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Cycle</b>                                                       | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Content</b>                                                     | <ul style="list-style-type: none"> <li>- Microstructure and properties of the matrix and reinforcing materials and their interaction</li> <li>- Development of composite materials</li> <li>- Mechanical and physical properties</li> <li>- Mechanics of Composite Materials</li> <li>- Laminate theory</li> <li>- Test methods</li> <li>- Non destructive testing</li> <li>- Failure mechanisms</li> <li>- Theoretical models for the prediction of properties</li> <li>- Application</li> </ul> |
| <b>Literature</b>                                                  | Hall, Clyne: Introduction to Composite materials, Cambridge University Press<br>Daniel, Ishai: Engineering Mechanics of Composites Materials, Oxford University Press<br>Mallick: Fibre-Reinforced Composites, Marcel Dekker, New York                                                                                                                                                                                                                                                            |

| Course L2614: Structure and properties of fibre-polymer-composites |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|--------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                         | Project-/problem-based Learning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Hrs/wk</b>                                                      | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>CP</b>                                                          | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Workload in Hours</b>                                           | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Lecturer</b>                                                    | Prof. Bodo Fiedler                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Language</b>                                                    | DE/EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Cycle</b>                                                       | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Content</b>                                                     | <p>The students receive the assignment in the form of a material design for test bodies made of fibre composites. Technical and normative requirements are listed in the assignment, all other required information comes from the lectures and exercises or the respective documents (electronically and in conversation).</p> <p>The procedure is specified in a milestone plan and enables the students to plan subtasks and thus work continuously. At the end of the project, different test specimens were tested in tensile or bending tests.</p> <p>In the individual project meetings, the conception (discussion of requirements and risks) is scrutinised. The calculations are analysed, the production methods are evaluated and determined. Materials are selected and the test specimens are manufactured according to standards. The quality and mechanical properties are checked and classified. At the end, a final report is prepared and the results are presented to all participants in the form of a presentation and discussed.</p> <p>Translated with <a href="https://www.DeepL.com/Translator">www.DeepL.com/Translator</a> (free version)</p> |
| <b>Literature</b>                                                  | Hall, Clyne: Introduction to Composite materials, Cambridge University Press<br>Daniel, Ishai: Engineering Mechanics of Composites Materials, Oxford University Press<br>Mallick: Fibre-Reinforced Composites, Marcel Dekker, New York                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

| Course L2613: Structure and properties of fibre-polymer-composites |                                                                                                                                                                                                                                        |
|--------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                         | Recitation Section (large)                                                                                                                                                                                                             |
| <b>Hrs/wk</b>                                                      | 1                                                                                                                                                                                                                                      |
| <b>CP</b>                                                          | 1                                                                                                                                                                                                                                      |
| <b>Workload in Hours</b>                                           | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                    |
| <b>Lecturer</b>                                                    | Prof. Bodo Fiedler                                                                                                                                                                                                                     |
| <b>Language</b>                                                    | EN                                                                                                                                                                                                                                     |
| <b>Cycle</b>                                                       | SoSe                                                                                                                                                                                                                                   |
| <b>Content</b>                                                     | <p>The contents of the lecture are repeated and deepened using practical examples.</p> <p>Calculations are carried out together or individually, and the results are discussed critically.</p>                                         |
| <b>Literature</b>                                                  | Hall, Clyne: Introduction to Composite materials, Cambridge University Press<br>Daniel, Ishai: Engineering Mechanics of Composites Materials, Oxford University Press<br>Mallick: Fibre-Reinforced Composites, Marcel Dekker, New York |

| Module M1425: Power electronics               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |  |        |    |
|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--------|----|
| Courses                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |  |        |    |
| Title                                         | Typ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  | Hrs/wk | CP |
| Power electronics (L2053)                     | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |  | 2      | 4  |
| Power electronics (L2054)                     | Recitation Section (small)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |  | 2      | 2  |
| <b>Module Responsible</b>                     | Prof. Martin Kaltschmitt                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |  |        |    |
| <b>Admission Requirements</b>                 | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |        |    |
| <b>Recommended Previous Knowledge</b>         | Basics of Electrical Engineering                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |  |        |    |
| <b>Educational Objectives</b>                 | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |        |    |
| <b>Professional Competence</b>                | <p>The students are taught the basics of power converter technology and modern power electronics. Furthermore, the essential properties of conventional and modern power semiconductors will be presented and their driving techniques will be presented. The students also learn about the most important circuit topologies of self-commutated power converters and their control methods.</p> <p>In addition to the basics of power converter commutation, the students learn methods for determining the on-state and switching losses of the components. Using simple examples, the participants will learn methods for the mathematical description of the transmission behavior of power electronic circuits.</p> <p>Students will be able to discuss problems in related topics in the field of photovoltaics and power electronics with fellow students.</p> <p>The students can independently access sources based on the main topics of the lectures and transfer the acquired knowledge to a wider field</p> |  |        |    |
| <i>Knowledge</i>                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |  |        |    |
| <i>Skills</i>                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |  |        |    |
| <b>Personal Competence</b>                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |  |        |    |
| <i>Social Competence</i>                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |  |        |    |
| <i>Autonomy</i>                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |  |        |    |
| <b>Workload in Hours</b>                      | Independent Study Time 124, Study Time in Lecture 56                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |        |    |
| <b>Credit points</b>                          | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |  |        |    |
| <b>Course achievement</b>                     | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |        |    |
| <b>Examination</b>                            | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |  |        |    |
| <b>Examination duration and scale</b>         | 120 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |  |        |    |
| <b>Assignment for the Following Curricula</b> | Electrical Engineering and Information Technology: Specialisation Control and Power Systems Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory<br>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |  |        |    |

| Course L2053: Power electronics |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|---------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                      | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Hrs/wk</b>                   | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>CP</b>                       | 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Workload in Hours</b>        | Independent Study Time 92, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Lecturer</b>                 | Prof. Klaus Hoffmann                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Language</b>                 | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Cycle</b>                    | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Content</b>                  | <ul style="list-style-type: none"> <li>Fundamentals of power electronics               <ul style="list-style-type: none"> <li>Classification of the power converters according to their internal and external mode of operation</li> <li>Presentation of modern converter systems</li> </ul> </li> <li>Introduction of power semiconductors               <ul style="list-style-type: none"> <li>Fields of application and limits of use of modern power semiconductors</li> <li>Power diodes and conventional power semiconductors (thyristor and GTO)</li> <li>Modern power semiconductors: power MOSFET, IGBT and IGCT</li> <li>On-state and switching losses</li> <li>Commutation processes in modern power converter circuits</li> <li>Development trends in the field of power semiconductors</li> </ul> </li> <li>Introduction to self-commutated converter circuits               <ul style="list-style-type: none"> <li>DC converter with turn-off power semiconductors</li> <li>Control method (pulse width modulation, tolerance band control)</li> <li>H-bridge topology with modern turn-off power semiconductors in clocked inverter and rectifier operation</li> <li>Three-phase bridge circuit with modern turn-off power semiconductors</li> </ul> </li> <li>Brief introduction to the line-commutated converter circuits</li> </ul> |
| <b>Literature</b>               | Hilfsblätter und Literaturhinweise werden im Rahmen der Vorlesung ausgeteilt.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

| Course L2054: Power electronics |                                                     |
|---------------------------------|-----------------------------------------------------|
| <b>Typ</b>                      | Recitation Section (small)                          |
| <b>Hrs/wk</b>                   | 2                                                   |
| <b>CP</b>                       | 2                                                   |
| <b>Workload in Hours</b>        | Independent Study Time 32, Study Time in Lecture 28 |
| <b>Lecturer</b>                 | Prof. Klaus Hoffmann                                |
| <b>Language</b>                 | DE                                                  |
| <b>Cycle</b>                    | SoSe                                                |
| <b>Content</b>                  | See interlocking course                             |
| <b>Literature</b>               | See interlocking course                             |



| Module M2109: Risk Management, Hydrogentechnology and Energy Trading |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |    |
|----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|----|
| Courses                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |    |
| Title                                                                | Typ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Hrs/wk | CP |
| Energy Trading (L0019)                                               | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1      | 1  |
| Energy Trading (L0020)                                               | Recitation Section (small)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1      | 1  |
| Risk Management in the Energy Industry (L1748)                       | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2      | 2  |
| Hydrogen Technology (L0060)                                          | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2      | 2  |
| Module Responsible                                                   | Prof. Martin Kaltschmitt                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |        |    |
| Admission Requirements                                               | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |        |    |
| Recommended Previous Knowledge                                       | none                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |        |    |
| Educational Objectives                                               | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |        |    |
| Professional Competence                                              | <div>Knowledge</div> <p>With completion of this module students can explain basics of risk management involving thematical adjacent contexts and can describe an optimal management of energy systems.</p> <p>Furthermore, students can reproduce solid theoretical knowledge about the potentials and applications of new information technologies in logistics and explain technical aspects of the use, production and processing of hydrogen.</p> <div>Skills</div> <p>With completion of this module students are able to evaluate risks of energy systems with respect to energy economic conditions in an efficient way. This includes that the students can assess the risks in operational planning of power plants from a technical, economic and ecological perspective.</p> <p>In this context, students can evaluate the potentials of logistics and information technology in particular on energy issues.</p> <p>In addition, students are able to describe the energy transfer medium hydrogen according to its applications, the given security and its existing service capacities and limits as well as to evaluate these aspects from a technical, environmental and economic perspective.</p> <div>Personal Competence</div> <div>Social Competence</div> <p>Students are able to discuss issues in the thematic fields in the renewable energy sector addressed within the module.</p> <div>Autonomy</div> <p>Students can independently exploit sources on the emphasis of the lectures and acquire the contained knowledge. In this way, they can recognize their lacks of knowledge and can consequently define the further workflow.</p> |        |    |
|                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |    |
|                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |    |
|                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |    |
|                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |    |
| Workload in Hours                                                    | Independent Study Time 96, Study Time in Lecture 84                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |        |    |
| Credit points                                                        | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |        |    |
| Course achievement                                                   | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |        |    |
| Examination                                                          | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |        |    |
| Examination duration and scale                                       | 180 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |        |    |
| Assignment for the Following Curricula                               | Aircraft Systems Engineering: Core Qualification: Elective Compulsory<br>Aeronautics: Core Qualification: Elective Compulsory<br>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |        |    |

| Course L0019: Energy Trading |                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                   | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Hrs/wk</b>                | 1                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>CP</b>                    | 1                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Workload in Hours</b>     | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Lecturer</b>              | Robert Gersdorf                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Language</b>              | DE                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Cycle</b>                 | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Content</b>               | <ul style="list-style-type: none"> <li>• Basic concepts and tradable products in energy markets</li> <li>• Primary energy markets</li> <li>• Electricity Markets</li> <li>• European Emissions Trading Scheme</li> <li>• Influence of renewable energy</li> <li>• Real options</li> <li>• Risk management</li> </ul> <p>Within the exercise the various tasks are actively discussed and applied to various cases of application.</p> |
| <b>Literature</b>            |                                                                                                                                                                                                                                                                                                                                                                                                                                       |

| Course L0020: Energy Trading |                                                     |
|------------------------------|-----------------------------------------------------|
| <b>Typ</b>                   | Recitation Section (small)                          |
| <b>Hrs/wk</b>                | 1                                                   |
| <b>CP</b>                    | 1                                                   |
| <b>Workload in Hours</b>     | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>              | Robert Gersdorf                                     |
| <b>Language</b>              | DE                                                  |
| <b>Cycle</b>                 | SoSe                                                |
| <b>Content</b>               | See interlocking course                             |
| <b>Literature</b>            | See interlocking course                             |

| Course L1748: Risk Management in the Energy Industry |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                           | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Hrs/wk</b>                                        | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>CP</b>                                            | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Workload in Hours</b>                             | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Lecturer</b>                                      | Dr. Christian Wulf                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Language</b>                                      | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Cycle</b>                                         | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Content</b>                                       | <ul style="list-style-type: none"> <li>• Basics of risk management <ul style="list-style-type: none"> <li>◦ Definition of terms</li> <li>◦ Risk types</li> <li>◦ Risk management process</li> <li>◦ Enterprise risk management</li> </ul> </li> <li>• Markets and instruments in energy trading <ul style="list-style-type: none"> <li>◦ Basics of futures and spot trading</li> <li>◦ Notation in energy markets</li> <li>◦ Options</li> </ul> </li> <li>• Kennzahlendefinition <ul style="list-style-type: none"> <li>◦ Assessing of market risks</li> <li>◦ Assessing of credit risks</li> <li>◦ Assessing of operational risks</li> <li>◦ Assessing of liquidity risks</li> </ul> </li> <li>• Risk monitoring and reporting</li> <li>• Risk treatment</li> </ul> |
| <b>Literature</b>                                    | <ul style="list-style-type: none"> <li>• Roggi, O. (2012): Risk Taking: A Corporate Governance Perspective, International Finance Corporation, New York</li> <li>• Hull, J. C. (2012): Options, Futures, and other Derivatives, 8. Auflage, Pearson Verlag, New York</li> <li>• Albrecht, P.; Maurer, R. (2008): Investment- und Risikomanagement, 3. Auflage, Schäffer-Poeschel Verlag, Stuttgart</li> <li>• Rittenberg, L.; Martens, F. (2012): Understanding and Communicating Risk Appetite, Treadway Commission, Durham</li> </ul>                                                                                                                                                                                                                              |

| Course L0060: Hydrogen Technology |                                                                                                                                                                                                                                                                                                                                                                          |
|-----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                        | Lecture                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Hrs/wk</b>                     | 2                                                                                                                                                                                                                                                                                                                                                                        |
| <b>CP</b>                         | 2                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Workload in Hours</b>          | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                      |
| <b>Lecturer</b>                   | Dr. Jose Bellosta von Colbe, Dr. Paul Jerabek                                                                                                                                                                                                                                                                                                                            |
| <b>Language</b>                   | DE                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Cycle</b>                      | SoSe                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Content</b>                    | <ol style="list-style-type: none"> <li>1. Energy economy</li> <li>2. Hydrogen economy</li> <li>3. Occurrence and properties of hydrogen</li> <li>4. Production of hydrogen (from hydrocarbons and by electrolysis)</li> <li>5. Separation and purification Storage and transport of hydrogen</li> <li>6. Security</li> <li>7. Fuel cells</li> <li>8. Projects</li> </ol> |
| <b>Literature</b>                 | <ul style="list-style-type: none"> <li>• Skriptum zur Vorlesung</li> <li>• Winter, Nitsch: Wasserstoff als Energieträger</li> <li>• Ullmann's Encyclopedia of Industrial Chemistry</li> <li>• Kirk, Othmer: Encyclopedia of Chemical Technology</li> <li>• Larminie, Dicks: Fuel cell systems explained</li> </ul>                                                       |

| Module M2139: District Heating         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |        |    |
|----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|----|
| Courses                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |        |    |
| Title                                  | Typ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Hrs/wk | CP |
| Combined Heat and Power (CHP) (L3430)  | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 2      | 2  |
| Pipeline-based Heat Supply (L3428)     | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 2      | 2  |
| Heat from Deep Geothermal Heat (L3429) | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 2      | 2  |
| Module Responsible                     | Prof. Arne Speerforck                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |        |    |
| Admission Requirements                 | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |        |    |
| Recommended Previous Knowledge         | Technical Thermodynamics I, II, Fluid Dynamics, Heat Transfer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |        |    |
| Educational Objectives                 | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |        |    |
| Professional Competence                | <p><i>Knowledge</i> Students are familiar with the technical fundamentals of energy conversion in combined heat and power plants, as well as the conduction-based heat transport and the utilization of deep geothermal energy. They are knowledgeable about the structure and content of relevant technical regulations. They can distinguish between various plant configurations, understand fundamental characteristics, and identify the advantages and disadvantages of different solutions. They are aware of current challenges and can categorize, develop, and evaluate transformation paths for different district heating systems.</p> <p><i>Skills</i> Students are capable of designing district heating networks and sizing the corresponding plant technology. They can apply calculation methods and technical regulations. They are able to quantify the potential of deep geothermal energy and calculate systems for combined heat and power. They can assess transformation paths for district heating networks and follow public discourse on the heat transition.</p> <p><i>Social Competence</i> The students can engage in goal-oriented discussions in small groups using various examples and thought experiments, develop a solution approach, and present it. They are able to independently formulate more in-depth questions within the framework of exercises and work out targeted solutions.</p> <p><i>Autonomy</i> Students are able to independently define tasks, develop the necessary knowledge based on the acquired knowledge, and use appropriate tools to implement them. In the exercises, students discuss the methods taught in the lectures using complex problems and critically analyze the results.</p> |        |    |
|                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |        |    |
|                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |        |    |
|                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |        |    |
| Workload in Hours                      | Independent Study Time 96, Study Time in Lecture 84                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |        |    |
| Credit points                          | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |        |    |
| Course achievement                     | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |        |    |
| Examination                            | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |        |    |
| Examination duration and scale         | 180 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |    |
| Assignment for the Following Curricula | Energy Systems: Specialisation Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |        |    |

| Course L3430: Combined Heat and Power (CHP) |                                                     |
|---------------------------------------------|-----------------------------------------------------|
| Typ                                         | Lecture                                             |
| Hrs/wk                                      | 2                                                   |
| CP                                          | 2                                                   |
| Workload in Hours                           | Independent Study Time 32, Study Time in Lecture 28 |
| Lecturer                                    | Dr. Kristin Abel-Günther                            |
| Language                                    | DE                                                  |
| Cycle                                       | SoSe                                                |
| Content                                     |                                                     |
| Literature                                  |                                                     |

| Course L3428: Pipeline-based Heat Supply |                                                     |
|------------------------------------------|-----------------------------------------------------|
| Typ                                      | Lecture                                             |
| Hrs/wk                                   | 2                                                   |
| CP                                       | 2                                                   |
| Workload in Hours                        | Independent Study Time 32, Study Time in Lecture 28 |
| Lecturer                                 | NN                                                  |
| Language                                 | DE                                                  |
| Cycle                                    | SoSe                                                |
| Content                                  |                                                     |
| Literature                               |                                                     |

| Course L3429: Heat from Deep Geothermal Heat |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|----------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                   | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Hrs/wk</b>                                | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>CP</b>                                    | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Workload in Hours</b>                     | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Lecturer</b>                              | Dr. Ben Norden                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Language</b>                              | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Cycle</b>                                 | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Content</b>                               | <ol style="list-style-type: none"> <li>1. Geological Background</li> <li>2. Hydrothermal targets for geothermal and aquifer storage applications</li> <li>3. Exploration and petrophysics supporting geothermal planning and site development</li> <li>4. Geological modeling and usage cases</li> </ol>                                                                                                                                                                                                                                                |
| <b>Literature</b>                            | <ul style="list-style-type: none"> <li>• Kaltschmitt et al. (eds): Erneuerbare Energien: Systemtechnik, Wirtschaftlichkeit, Umweltaspekte. Springer, 6. Aufl. 2020.</li> <li>• Livescu, S. &amp; Dindoruk, B (eds): Geothermal Energy Engineering, Elsevier, 2025.</li> <li>• Bloemendal, M. et al., 2014: How to achieve optimal and sustainable use of the subsurface for Aquifer Thermal Energy Storage, Energy Policy, Volume 66, <a href="https://doi.org/10.1016/j.enpol.2013.11.034">https://doi.org/10.1016/j.enpol.2013.11.034</a>.</li> </ul> |

| Module M1354: Advanced Fuels                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
|--------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|-------------------------------------------------------------|
| Courses                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
| Title                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Type                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Hrs/wk              | CP                                                          |
| Second generation biofuels and electricity based fuels (L2414)           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2                   | 2                                                           |
| Carbon dioxide as an economic determinant in the mobility sector (L1926) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1                   | 1                                                           |
| Mobility and climate protection (L2416)                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Recitation Section (small)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 2                   | 2                                                           |
| Sustainability aspects and regulatory framework (L2415)                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1                   | 1                                                           |
| Module Responsible                                                       | Dr. Marvin Scherzinger                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
| Admission Requirements                                                   | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
| Recommended Previous Knowledge                                           | Bachelor degree in Process Engineering, Bioprocess Engineering or Energy- and Environmental Engineering                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
| Educational Objectives                                                   | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
| <b>Professional Competence</b>                                           | <i>Knowledge</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Within the module, students learn about different provision pathways for the production of advanced fuels (biofuels like e.g. alcohol-to-jet; electricity-based fuels like e.g. power-to-liquid). The different processes chains are explained and the regulatory framework for sustainable fuel production is examined. This includes, for example, the requirements of the Renewable Energies Directive II and the conditions and aspects for a market ramp-up of these fuels. For the holistic assessment of the various fuel options, they are also examined under environmental and economic factors.                                                                      |                     |                                                             |
|                                                                          | <i>Skills</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | After successfully participating, the students are able to solve simulation and application tasks of renewable energy technology: <ul style="list-style-type: none"><li>• Module-spanning solutions for the design and presentation of fuel production processes resp. the fuel provision chains</li><li>• Comprehensive analysis of various fuel production options in technical, ecological and economic terms</li></ul> Through active discussions of the various topics within the lectures and exercises of the module, the students improve their understanding and application of the theoretical foundations and are thus able to transfer the learned to the practice. |                     |                                                             |
|                                                                          | <b>Personal Competence</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
|                                                                          | <i>Social Competence</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | The students can discuss scientific tasks in a subject-specific and interdisciplinary way and develop joint solutions.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                     |                                                             |
|                                                                          | <i>Autonomy</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | The students are able to access independent sources about the questions to be addressed and to acquire the necessary knowledge. They are able to assess their respective learning situation concretely in consultation with their supervisor and to define further questions and solutions.                                                                                                                                                                                                                                                                                                                                                                                     |                     |                                                             |
| Workload in Hours                                                        | Independent Study Time 96, Study Time in Lecture 84                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
| Credit points                                                            | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
| Course achievement                                                       | Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Bonus                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Form                | Description                                                 |
|                                                                          | Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 20 %                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Written elaboration | Details werden in der ersten Veranstaltung bekannt gegeben. |
| Examination                                                              | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
| Examination duration and scale                                           | 120 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |
| Assignment for the Following Curricula                                   | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory<br>Environmental Engineering: Specialisation Energy and Resources: Elective Compulsory<br>Aircraft Systems Engineering: Core Qualification: Elective Compulsory<br>Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory<br>Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory<br>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                                                             |

| Course L2414: Second generation biofuels and electricity based fuels |                                                                                                                                                                                                                                                                                                |
|----------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                           | Lecture                                                                                                                                                                                                                                                                                        |
| <b>Hrs/wk</b>                                                        | 2                                                                                                                                                                                                                                                                                              |
| <b>CP</b>                                                            | 2                                                                                                                                                                                                                                                                                              |
| <b>Workload in Hours</b>                                             | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                            |
| <b>Lecturer</b>                                                      | Dr. Marvin Scherzinger                                                                                                                                                                                                                                                                         |
| <b>Language</b>                                                      | DE/EN                                                                                                                                                                                                                                                                                          |
| <b>Cycle</b>                                                         | WiSe                                                                                                                                                                                                                                                                                           |
| <b>Content</b>                                                       | <ul style="list-style-type: none"> <li>General overview of various power-based fuels and their process paths, including power-to-liquid process (Fischer-Tropsch synthesis, methanol synthesis), power-to-gas (Sabatier process)</li> <li>Origin, production and use of these fuels</li> </ul> |
| <b>Literature</b>                                                    | <ul style="list-style-type: none"> <li>Vorlesungsskript</li> </ul>                                                                                                                                                                                                                             |

| Course L1926: Carbon dioxide as an economic determinant in the mobility sector |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|--------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                                     | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Hrs/wk</b>                                                                  | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>CP</b>                                                                      | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Workload in Hours</b>                                                       | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Lecturer</b>                                                                | Dr. Karsten Wilbrand                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Language</b>                                                                | DE/EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Cycle</b>                                                                   | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Content</b>                                                                 | <ul style="list-style-type: none"> <li>General overview of various advanced biofuels and their process pathways (including gas-to-liquid, HEFA and Alcohol-to-Jet processes)</li> <li>Origin, production and use of these fuels</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Literature</b>                                                              | <ul style="list-style-type: none"> <li>Babu, V.: Biofuels Production. Beverly, Mass: Scrivener [u.a.], 2013</li> <li>Olsson, L.: Biofuels. Berlin, Heidelberg: Springer-Verlag Berlin Heidelberg, 2007</li> <li>William, L. L.: Distillation Design and Control Using Aspen Simulation; ISBN-10: 0-471-77888-5</li> <li>Perry, R.; Green, R.: Perry's Chemical Engineers' Handbook, 8th Edition, McGraw Hill Professional, 20</li> <li>Sinnott, R. K.: Chemical Engineering Design, Elsevier, 2014</li> <li>Kaltschmitt, M.; Neuling, U. (Ed.): Biokerosene - Status and Prospects; Springer, Berlin, Heidelberg, 2018</li> </ul> |

| Course L2416: Mobility and climate protection |                                                                                                                                                                                                                                                                                                                                                                                                        |
|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                    | Recitation Section (small)                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Hrs/wk</b>                                 | 2                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>CP</b>                                     | 2                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Workload in Hours</b>                      | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                    |
| <b>Lecturer</b>                               | Dr. Benedikt Buchspies, Dr. Karsten Wilbrand                                                                                                                                                                                                                                                                                                                                                           |
| <b>Language</b>                               | DE/EN                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Cycle</b>                                  | WiSe                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Content</b>                                | <p>Application of the acquired theoretical knowledge from the respective lectures on the basis of concrete tasks from practice</p> <ul style="list-style-type: none"> <li>Design and simulation of sub-processes of production processes in Aspen Plus ®</li> <li>Ecological and economic analysis of fuel supply paths</li> <li>Classification of case studies into applicable regulations</li> </ul> |
| <b>Literature</b>                             | <ul style="list-style-type: none"> <li>Skriptum zur Vorlesung</li> <li>Aspen Plus® - Aspen Plus User Guide</li> </ul>                                                                                                                                                                                                                                                                                  |

| Course L2415: Sustainability aspects and regulatory framework |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|---------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                    | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Hrs/wk</b>                                                 | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>CP</b>                                                     | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Workload in Hours</b>                                      | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Lecturer</b>                                               | Dr. Benedikt Buchspies                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Language</b>                                               | DE/EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Cycle</b>                                                  | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Content</b>                                                | <p>Holistic examination of the different fuel paths with the following main topics, among others:</p> <ul style="list-style-type: none"> <li>• Consideration of the environmental impact of the various alternative fuels</li> <li>• Economic consideration of the different alternative fuels</li> <li>• Regulatory framework for alternative fuels</li> <li>• Certification of alternative fuels</li> <li>• Market introduction models of alternative fuels</li> </ul>                      |
| <b>Literature</b>                                             | <ul style="list-style-type: none"> <li>• European Commission - Joint Research Center (2010): International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed guidance. Joint Research Center (JRC) Institut for Environment and Sustainability, Luxembourg</li> <li>• Richtlinie (EU) 2018/2001 des Europäischen Parlaments und des Rates vom 11. Dezember 2018 zur Förderung der Nutzung von Energie aus erneuerbaren Quellen</li> </ul> |



| Module M1909: System Simulation                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |               |           |
|--------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|-----------|
| <b>Courses</b>                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |               |           |
| <b>Title</b>                                                                                                                                     | <b>Typ</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>Hrs/wk</b> | <b>CP</b> |
| System Simulation Modul (L3150)                                                                                                                  | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 3             | 4         |
| System Simulation Modul (L3151)                                                                                                                  | Recitation Section (large)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2             | 2         |
| <b>Module Responsible</b>                                                                                                                        | Prof. Arne Speerforck                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |               |           |
| <b>Admission Requirements</b>                                                                                                                    | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |               |           |
| <b>Recommended Previous Knowledge</b>                                                                                                            | Mathematics I-III, Computer Science, Engineering Thermodynamics I, II, Fluid Dynamics, Heat Transfer, Control Systems                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |               |           |
| <b>Educational Objectives</b>                                                                                                                    | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |               |           |
| <b>Professional Competence</b><br><i>Knowledge</i><br><i>Skills</i><br><b>Personal Competence</b><br><i>Social Competence</i><br><i>Autonomy</i> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |               |           |
| <b>Workload in Hours</b>                                                                                                                         | Independent Study Time 110, Study Time in Lecture 70                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |               |           |
| <b>Credit points</b>                                                                                                                             | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |               |           |
| <b>Course achievement</b>                                                                                                                        | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |               |           |
| <b>Examination</b>                                                                                                                               | Oral exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |               |           |
| <b>Examination duration and scale</b>                                                                                                            | 30 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |               |           |
| <b>Assignment for the Following Curricula</b>                                                                                                    | Energy Systems: Specialisation Energy Systems: Compulsory<br>Energy Systems: Specialisation Green Energy Technologies: Elective Compulsory<br>Aircraft Systems Engineering: Core Qualification: Elective Compulsory<br>Aeronautics: Core Qualification: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Specialisation Product Development: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Specialisation Production: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Specialisation Materials: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Production: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Materials: Elective Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory |               |           |

| Course L3150: System Simulation Modul |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                            | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Hrs/wk</b>                         | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>CP</b>                             | 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Workload in Hours</b>              | Independent Study Time 78, Study Time in Lecture 42                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Lecturer</b>                       | Prof. Arne Speerforck, Dr. Johannes Brunnemann                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Language</b>                       | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Cycle</b>                          | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Content</b>                        | <p>Lecture about equation-based, physical modelling using the modelling language Modelica and the free simulation tool OpenModelica 1.17.0.</p> <ul style="list-style-type: none"> <li>• Instruction and modelling of physical processes</li> <li>• Modelling and limits of model</li> <li>• Time constant, stiffness, stability, step size</li> <li>• Terms of object orientated programming</li> <li>• Differential equations of simple systems</li> <li>• Introduction into Modelica</li> <li>• Introduction into simulation tool</li> <li>• Example:Hydraulic systems and heat transfer</li> <li>• Example: System with different subsystems</li> </ul>                                                                                                                                                                                     |
| <b>Literature</b>                     | <p>[1] Modelica Association: "Modelica Language Specification - Version 3.5", Linköping, Sweden, 2021.</p> <p>[2] OpenModelica: OpenModelica 1.17.0, <a href="https://www.openmodelica.org">https://www.openmodelica.org</a> (siehe Download), 2021.</p> <p>[3] M. Tiller: "Modelica by Example", <a href="https://book.xogeny.com">https://book.xogeny.com</a>, 2014.</p> <p>[4] M. Otter, H. Elmqvist, et al.: "Objektorientierte Modellierung Physikalischer Systeme", at- Automatisierungstechnik (german), Teil 1 - 17, Oldenbourg Verlag, 1999 - 2000.</p> <p>[5] P. Fritzson: "Principles of Object-Oriented Modeling and Simulation with Modelica 3.3", Wiley-IEEE Press, New York, 2015.</p> <p>[6] P. Fritzson: "Introduction to Modeling and Simulation of Technical and Physical Systems with Modelica", Wiley, New York, 2011.</p> |

| Course L3151: System Simulation Modul |                                                     |
|---------------------------------------|-----------------------------------------------------|
| <b>Typ</b>                            | Recitation Section (large)                          |
| <b>Hrs/wk</b>                         | 2                                                   |
| <b>CP</b>                             | 2                                                   |
| <b>Workload in Hours</b>              | Independent Study Time 32, Study Time in Lecture 28 |
| <b>Lecturer</b>                       | Prof. Arne Speerforck, Dr. Johannes Brunnemann      |
| <b>Language</b>                       | DE                                                  |
| <b>Cycle</b>                          | WiSe                                                |
| <b>Content</b>                        | See interlocking course                             |
| <b>Literature</b>                     | See interlocking course                             |

| Module M1710: Smart Grid Technologies         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |  |        |    |
|-----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--------|----|
| Courses                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |  |        |    |
| Title                                         | Typ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |  | Hrs/wk | CP |
| Smart Grid Technologies (L2706)               | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |  | 3      | 4  |
| Smart Grid Technologies (L2707)               | Project-/problem-based Learning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |  | 2      | 2  |
| <b>Module Responsible</b>                     | Prof. Christian Becker                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |  |        |    |
| <b>Admission Requirements</b>                 | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |  |        |    |
| <b>Recommended Previous Knowledge</b>         | Fundamentals of Electrical Engineering,<br>Introduction to Control Systems,<br>Mathematics I, II, III<br>Electrical Power Systems I<br>Electrical Power Systems II                                                                                                                                                                                                                                                                                                                                                                                             |  |        |    |
| <b>Educational Objectives</b>                 | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |  |        |    |
| <b>Professional Competence</b>                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |  |        |    |
| <i>Knowledge</i>                              | Students are able to explain in detail and critically evaluate methods and technologies for operation of smart grids (i.e. intelligent distribution grids).                                                                                                                                                                                                                                                                                                                                                                                                    |  |        |    |
| <i>Skills</i>                                 | With completion of this module the students are able to analyze the impact of emerging technologies (such as renewables, energy storage and demand response) on the electric power system. They can formulate and apply computational intelligence techniques to power system operation problems. They can also explain what ICT technologies (such as digital twins and IoT) are relevant and suitable for distribution grid operation.                                                                                                                       |  |        |    |
| <b>Personal Competence</b>                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |  |        |    |
| <i>Social Competence</i>                      | The students can participate in specialized and interdisciplinary discussions, advance ideas and represent their own work results in front of others.                                                                                                                                                                                                                                                                                                                                                                                                          |  |        |    |
| <i>Autonomy</i>                               | Students can independently tap knowledge of the emphasis of the lectures and apply it within further research activities.                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |        |    |
| <b>Workload in Hours</b>                      | Independent Study Time 110, Study Time in Lecture 70                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |  |        |    |
| <b>Credit points</b>                          | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |  |        |    |
| <b>Course achievement</b>                     | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |  |        |    |
| <b>Examination</b>                            | Presentation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |  |        |    |
| <b>Examination duration and scale</b>         | 30 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |  |        |    |
| <b>Assignment for the Following Curricula</b> | Electrical Engineering and Information Technology: Specialisation Control and Power Systems Engineering: Elective Compulsory<br>Energy Systems: Specialisation Energy Systems: Elective Compulsory<br>Energy Systems: Specialisation Green Energy Technologies: Elective Compulsory<br>International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory<br>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory |  |        |    |

| Course L2706: Smart Grid Technologies |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|---------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                            | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Hrs/wk</b>                         | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>CP</b>                             | 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Workload in Hours</b>              | Independent Study Time 78, Study Time in Lecture 42                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Lecturer</b>                       | Prof. Christian Becker, Dr. Payam Teimourzadeh Baboli                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Language</b>                       | DE/EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Cycle</b>                          | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Content</b>                        | <p><b>Introduction to Smart Grids</b></p> <ul style="list-style-type: none"> <li>• Intelligent Distribution Grids</li> <li>• Paradigm shifts: Digitalization &amp; Sustainability</li> </ul> <p><b>Emerging technologies in distribution grids</b></p> <ul style="list-style-type: none"> <li>• Distributed Energy Resource (DER)</li> <li>• Battery Energy Storage (BES) technologies</li> <li>• Sector-coupling &amp; EV/V2G</li> <li>• Microgrids, Inverter-based Systems</li> <li>• Modelling and control of PV &amp; BESS</li> </ul> <p><b>Distribution grid management &amp; analysis</b></p> <ul style="list-style-type: none"> <li>• Distribution grid structure (Hamburg example)</li> <li>• Distribution grid management and operation architecture and functions <ul style="list-style-type: none"> <li>◦ Fault Detection, Isolation &amp; Restoration</li> <li>◦ Self-Healing in distribution systems</li> <li>◦ Volt-Var Optimization</li> <li>◦ Distribution Load Flow</li> </ul> </li> <li>• Demand Side Management &amp; Demand Response</li> <li>• Lab exercise (Smart Grid Operation)</li> </ul> <p><b>Computational intelligence and optimization techniques in Smart Grids</b></p> <ul style="list-style-type: none"> <li>• Computational challenges in Smart grid</li> <li>• Heuristic &amp; Analytic Optimization Methods</li> <li>• Intelligent Systems (Expert Systems, ML/AL)</li> <li>• Applications (optimal load flow, reactive capacitor placement)</li> <li>• Lab exercise (optimization formulation)</li> </ul> <p><b>ICT Technologies for Smart Grids</b></p> <ul style="list-style-type: none"> <li>• Advanced Metering Technologies: Smart Meters, RTU, PMU</li> <li>• Telecommunication Systems in Smart Grids (network basics and technologies)</li> <li>• Interoperability in Smart grids <ul style="list-style-type: none"> <li>◦ Smart Grid Architecture Model</li> <li>◦ Automation and Communication standards (IEC 61850, c37.118)</li> </ul> </li> <li>• Cyber security</li> <li>• Lab exercise (Grid automation protocols)</li> </ul> <p><b>Practical lesson-learned: Stromnetz Hamburg (SNH) perspective</b></p> <ul style="list-style-type: none"> <li>• Definition of Smart Grid and its requirements from industry view</li> <li>• Grid digitalization - examples of industrial projects</li> <li>• Flexible load management</li> <li>• Electromobility &amp; transportation sector integration</li> </ul> <p><b>Study visits:</b></p> <ul style="list-style-type: none"> <li>• Digital Substation in Harburg</li> <li>• Electric Bus charging station</li> </ul> <p>Stromnetz Hamburg Control Center</p> |
| <b>Literature</b>                     | <ul style="list-style-type: none"> <li>• Buchholz and Styczynski - 2020 - "Smart Grids: Fundamentals and Technologies in Electric Power Systems of the Future", Springer</li> <li>• Bernardon and Garcia - 2018 - "Smart Operation for Power Distribution Systems: Concepts and Applications", Springer</li> <li>• Momoh, 2012; "Smart Grid: Fundamentals of Design and Analysis", Wiley</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

| Course L2707: Smart Grid Technologies |                                                       |
|---------------------------------------|-------------------------------------------------------|
| <b>Typ</b>                            | Project-/problem-based Learning                       |
| <b>Hrs/wk</b>                         | 2                                                     |
| <b>CP</b>                             | 2                                                     |
| <b>Workload in Hours</b>              | Independent Study Time 32, Study Time in Lecture 28   |
| <b>Lecturer</b>                       | Prof. Christian Becker, Dr. Payam Teimourzadeh Baboli |
| <b>Language</b>                       | DE/EN                                                 |
| <b>Cycle</b>                          | WiSe                                                  |
| <b>Content</b>                        | See interlocking course                               |
| <b>Literature</b>                     | See interlocking course                               |

| Module M2175: Transport Processes                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                 |                  |                   |
|-------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|------------------|-------------------|
| Courses                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                 |                  |                   |
| Title                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Type                            | Hrs/wk           | CP                |
| Multiphase Flows (L0104)                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Lecture                         | 2                | 2                 |
| Reactor design under consideration of local transport processes (L0105) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Project-/problem-based Learning | 2                | 2                 |
| Heat & Mass Transfer in Process Engineering (L0103)                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Lecture                         | 2                | 2                 |
| Module Responsible                                                      | Prof. Michael Schlüter                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                 |                  |                   |
| Admission Requirements                                                  | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                 |                  |                   |
| Recommended Previous Knowledge                                          | All lectures from the undergraduate studies, especially mathematics, chemistry, thermodynamics, fluid mechanics, heat- and mass transfer.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                 |                  |                   |
| Educational Objectives                                                  | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                 |                  |                   |
| <b>Professional Competence</b><br><i>Knowledge</i>                      | <p>Students are able to:</p> <ul style="list-style-type: none"><li>describe transport processes in single- and multiphase flows and they know the analogy between heat- and mass transfer as well as the limits of this analogy.</li><li>explain the main transport laws and their application as well as the limits of application.</li><li>describe how transport coefficients for heat- and mass transfer can be derived experimentally.</li><li>compare different multiphase reactors like trickle bed reactors, pipe reactors, stirring tanks and bubble column reactors.</li><li>are known. The Students are able to perform mass and energy balances for different kind of reactors. Further more the industrial application of multiphase reactors for heat- and mass transfer are known.</li></ul>                                                                                                                                                                                                                                              |                                 |                  |                   |
| <i>Skills</i>                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                 |                  |                   |
| <b>Personal Competence</b><br><i>Social Competence</i>                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                 |                  |                   |
| <i>Autonomy</i>                                                         | The students are able to discuss in international teams in english and develop an approach under pressure of time.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                 |                  |                   |
| <b>Workload in Hours</b>                                                | Independent Study Time 96, Study Time in Lecture 84                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                 |                  |                   |
| <b>Credit points</b>                                                    | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                 |                  |                   |
| Course achievement                                                      | Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Bonus                           | Form             | Description       |
|                                                                         | Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | None                            | Group discussion | Gruppendiskussion |
| Examination                                                             | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                 |                  |                   |
| Examination duration and scale                                          | 15 min Presentation + 90 min multiple choice written examen                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                 |                  |                   |
| <b>Assignment for the Following Curricula</b>                           | <p>Bioprocess Engineering: Core Qualification: Compulsory</p> <p>Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory</p> <p>Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory</p> <p>Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory</p> <p>Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory</p> <p>Energy Systems: Specialisation Energy Systems: Elective Compulsory</p> <p>Energy Systems: Specialisation Green Energy Technologies: Elective Compulsory</p> <p>International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory</p> <p>International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory</p> <p>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory</p> <p>Process Engineering: Core Qualification: Compulsory</p> |                                 |                  |                   |

| Course L0104: Multiphase Flows |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|--------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                     | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Hrs/wk</b>                  | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>CP</b>                      | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Workload in Hours</b>       | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Lecturer</b>                | Prof. Michael Schlüter                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Language</b>                | EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Cycle</b>                   | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Content</b>                 | <ul style="list-style-type: none"> <li>• Interfaces in MPF (boundary layers, surfactants)</li> <li>• Hydrodynamics &amp; pressure drop in Film Flows</li> <li>• Hydrodynamics &amp; pressure drop in Gas-Liquid Pipe Flows</li> <li>• Hydrodynamics &amp; pressure drop in Bubbly Flows</li> <li>• Mass Transfer in Film Flows</li> <li>• Mass Transfer in Gas-Liquid Pipe Flows</li> <li>• Mass Transfer in Bubbly Flows</li> <li>• Reactive mass Transfer in Multiphase Flows</li> <li>• Film Flow: Application Trickle Bed Reactors</li> <li>• Pipe Flow: Application Turbular Reactors</li> <li>• Bubbly Flow: Application Bubble Column Reactors</li> </ul>                                                                                                                                                                      |
| <b>Literature</b>              | <p>Brauer, H.: Grundlagen der Einphasen- und Mehrphasenströmungen. Verlag Sauerländer, Aarau, Frankfurt (M), 1971.</p> <p>Clift, R.; Grace, J.R.; Weber, M.E.: Bubbles, Drops and Particles, Academic Press, New York, 1978.</p> <p>Fan, L.-S.; Tsuchiya, K.: Bubble Wake Dynamics in Liquids and Liquid-Solid Suspensions, Butterworth-Heinemann Series in Chemical Engineering, Boston, USA, 1990.</p> <p>Hewitt, G.F.; Delhay, J.M.; Zuber, N. (Ed.): Multiphase Science and Technology. Hemisphere Publishing Corp, Vol. 1/1982 bis Vol. 6/1992.</p> <p>Kolev, N.I.: Multiphase flow dynamics. Springer, Vol. 1 and 2, 2002.</p> <p>Levy, S.: Two-Phase Flow in Complex Systems. Verlag John Wiley &amp; Sons, Inc, 1999.</p> <p>Crowe, C.T.: Multiphase Flows with Droplets and Particles. CRC Press, Boca Raton, Fla, 1998.</p> |

| Course L0105: Reactor design under consideration of local transport processes |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                                    | Project-/problem-based Learning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Hrs/wk</b>                                                                 | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>CP</b>                                                                     | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Workload in Hours</b>                                                      | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Lecturer</b>                                                               | Prof. Michael Schlüter                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Language</b>                                                               | EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Cycle</b>                                                                  | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Content</b>                                                                | <p>In this Problem-Based Learning unit the students have to design a multiphase reactor for a fast chemical reaction concerning optimal hydrodynamic conditions of the multiphase flow.</p> <p>The four students in each team have to:</p> <ul style="list-style-type: none"> <li>• collect and discuss material properties and equations for design from the literature,</li> <li>• calculate the optimal hydrodynamic design,</li> <li>• check the plausibility of the results critically,</li> <li>• write an exposé with the results.</li> </ul> <p>This exposé will be used as basis for the discussion within the oral group examen of each team.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Literature</b>                                                             | <p>Bird, R.B.; Stewart, W.R.; Lightfoot, E.N.: Transport Phenomena, John Wiley &amp; Sons Inc (2007), ISBN 978-0-470-11539-8.</p> <p>Brauer, H.; Mewes, D.: Stoffaustausch einschließlich chemischer Reaktion; Verlag Sauerländer, Aarau und Frankfurt am Main (1971), ISBN: 3794100085.</p> <p>Brauer, H.: Grundlagen der Einphasen- und Mehrphasenströmungen, Sauerländer, 1971,</p> <p>Clift, R.; Grace, J.R.; Weber, M.E.: Bubbles, Drops, and Particles, Verlag Academic Press, 1978, ISBN 012176950X, 9780121769505</p> <p>Deckwer, W.-D.: Reaktionstechnik in Blasensäulen, Salle Verlag und Verlag Sauerländer, Aarau, Frankfurt am Main, Berlin, München, Salzburg (1985), DOI 10.1002/CITE.330590530</p> <p>Deckwer, W.-D.: Bubble Column Reactors. Wiley, New York (1992), DOI 10.1002/AIC.690380821.</p> <p>Fan, L.; Tsuchiya, K.: Bubble wake dynamics in liquids and liquid-solid suspension. Butterworth-Heinemann, (1990), DOI 10.1016/c2009-0-24002-5.</p> <p>Kraume, M., Transportvorgänge in der Verfahrenstechnik, Springer Berlin, 2020, ISBN 978-3-662-60392-5.</p> <p>Lienhard, J. H. (2019). A Heat Transfer Textbook, Dover Publications. ISBN:9780486837352, 0486837351.</p> |



| Course L0103: Heat & Mass Transfer in Process Engineering |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|-----------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Hrs/wk</b>                                             | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>CP</b>                                                 | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Workload in Hours</b>                                  | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Lecturer</b>                                           | Prof. Michael Schlüter                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Language</b>                                           | EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Cycle</b>                                              | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Content</b>                                            | <ul style="list-style-type: none"> <li>• Introduction - Transport Processes in Chemical Engineering</li> <li>• Molecular Heat- and Mass Transfer: Applications of Fourier's and Fick's Law</li> <li>• Convective Heat and Mass Transfer: Applications in Process Engineering</li> <li>• Unsteady State Transport Processes: Cooling &amp; Drying</li> <li>• Transport at fluidic Interfaces: Two Film, Penetration, Surface Renewal</li> <li>• Transport Laws &amp; Balance Equations with turbulence, sinks and sources</li> <li>• Experimental Determination of Transport Coefficients</li> <li>• Design and Scale Up of Reactors for Heat- and Mass Transfer</li> <li>• Reactive Mass Transfer</li> <li>• Processes with Phase Changes - Evaporization and Condensation</li> <li>• Radiative Heat Transfer - Fundamentals</li> <li>• Radiative Heat Transfer - Solar Energy</li> </ul> |
| <b>Literature</b>                                         | <ol style="list-style-type: none"> <li>1. Baehr, Stephan: Heat and Mass Transfer, Wiley 2002.</li> <li>2. Bird, Stewart, Lightfoot: Transport Phenomena, Springer, 2000.</li> <li>3. John H. Lienhard: A Heat Transfer Textbook, Phlogiston Press, Cambridge Massachusetts, 2008.</li> <li>4. Myers: Analytical Methods in Conduction Heat Transfer, McGraw-Hill, 1971.</li> <li>5. Incropera, De Witt: Fundamentals of Heat and Mass Transfer, Wiley, 2002.</li> <li>6. Beek, Muttzall: Transport Phenomena, Wiley, 1983.</li> <li>7. Crank: The Mathematics of Diffusion, Oxford, 1995.</li> <li>8. Madhusudana: Thermal Contact Conductance, Springer, 1996.</li> <li>9. Treybal: Mass-Transfer-Operation, McGraw-Hill, 1987.</li> </ol>                                                                                                                                               |

## Specialization Wind Energy Systems

Within the specialization "Wind Energy Systems" advanced knowledge for the utilization of wind energy in the offshore as well as in the onshore sector is provided. In particular, maritime and logistical constraints during the installation and use of offshore wind farms are discussed. In this context, the management of risks which may occur during construction and operation of such large energy projects are explained.

In addition, in a separate module, the material-specific basis for the composition of components of wind turbines is provided.

### Module M1133: Port Logistics

| Courses                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                            |                     |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|---------------------|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Title                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Typ                        | Hrs/wk              | CP          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Port Logistics (L0686)                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Lecture                    | 2                   | 3           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Port Logistics (L1473)                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Recitation Section (small) | 2                   | 3           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Module Responsible                     | Prof. Carlos Jahn                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                            |                     |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Admission Requirements                 | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                            |                     |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Recommended Previous Knowledge         | none                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                            |                     |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Educational Objectives                 | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                            |                     |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Professional Competence                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                            |                     |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Knowledge                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                            |                     |             | Th                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                            |                     |             | After completing the module, students can...                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                            |                     |             | <ul style="list-style-type: none"><li>reflect on the development of seaports (in terms of the functions of the ports and the corresponding terminals, as well as the relevant operator models) and place them in their historical context;</li><li>explain and evaluate different types of seaport terminals and their specific characteristics (cargo, transshipment technologies, logistic functional areas);</li><li>analyze common planning tasks (e.g. berth planning, stowage planning, yard planning) at seaport terminals and develop suitable approaches (in terms of methods and tools) to solve these planning tasks;</li><li>identify future developments and trends regarding the planning and control of innovative seaport terminals and discuss them in a problem-oriented manner.</li></ul> |
| Skills                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                            |                     |             | After completing the module, students will be able to...                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|                                        | <ul style="list-style-type: none"><li>recognize functional areas in ports and seaport terminals;</li><li>define and evaluate suitable operating systems for container terminals;</li><li>perform static calculations with regard to given boundary conditions, e.g. required capacity (parking spaces, equipment requirements, quay wall length, port access) on selected terminal types;</li><li>reliably estimate which boundary conditions influence common logistics indicators in the static planning of selected terminal types and to what extent.</li></ul> |                            |                     |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Personal Competence                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                            |                     |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Social Competence                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                            |                     |             | After completing the module, students can...                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                            |                     |             | <ul style="list-style-type: none"><li>transfer the acquired knowledge to further questions of port logistics;</li><li>discuss and successfully organize extensive task packages in small groups;</li><li>in small groups, document work results in writing in an understandable form and present them to an appropriate extent.</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Autonomy                               | After completing the module, the students are able to...                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                            |                     |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|                                        | <ul style="list-style-type: none"><li>research and select specialist literature, including standards, guidelines and journal papers, and to develop the contents independently;</li><li>submit own parts in an extensive written elaboration in small groups in due time and to present them jointly within a fixed time frame.</li></ul>                                                                                                                                                                                                                           |                            |                     |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Workload in Hours                      | Independent Study Time 124, Study Time in Lecture 56                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                            |                     |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Credit points                          | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                            |                     |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Course achievement                     | Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Bonus                      | Form                | Description |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|                                        | No                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 15 %                       | Written elaboration |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Examination                            | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                            |                     |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Examination duration and scale         | 120 minutes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                            |                     |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Assignment for the Following Curricula | Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Logistics: Elective Compulsory<br>Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory<br>Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory                                                                                                                                                                        |                            |                     |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

|  |                                                                                                                                                                                                                                                                                                                                                                 |
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|  | Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory<br>Naval Architecture and Ocean Engineering: Core Qualification: Elective Compulsory<br>Naval Architecture and Ocean Engineering: Core Qualification: Elective Compulsory<br><del>Theoretical Mechanical Engineering: Specialisation Maritime Technology: Elective Compulsory</del> |
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| Course L0686: Port Logistics |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                   | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Hrs/wk</b>                | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>CP</b>                    | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Workload in Hours</b>     | Independent Study Time 62, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Lecturer</b>              | Prof. Carlos Jahn                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Language</b>              | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Cycle</b>                 | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Content</b>               | <p>Port Logistics deals with the planning, control, execution and monitoring of material flows and the associated information flows in the port system and its interfaces to numerous actors inside and outside the port area.</p> <p>The extraordinary role of maritime transport in international trade requires very efficient ports. These must meet numerous requirements in terms of economy, speed, safety and the environment. Against this background, the lecture Port Logistics deals with the planning, control, execution and monitoring of material flows and the associated information flows in the port system and its interfaces to numerous actors inside and outside the port area. The aim of the lecture Port Logistics is to convey an understanding of structures and processes in ports. The focus will be on different types of terminals, their characteristic layouts and the technical equipment used as well as the ongoing digitization and interaction of the players involved.</p> <p>In addition, renowned guest speakers from science and practice will be regularly invited to discuss some lecture-relevant topics from alternative perspectives.</p> <p>The following contents will be conveyed in the lectures:</p> <ul style="list-style-type: none"> <li>• Instruction of structures and processes in the port</li> <li>• Planning, control, implementation and monitoring of material and information flows in the port</li> <li>• Fundamentals of different terminals, characteristic layouts and the technical equipment used</li> <li>• Handling of current issues in port logistics</li> </ul> |
| <b>Literature</b>            | <ul style="list-style-type: none"> <li>• Biebig, Peter and Althof, Wolfgang and Wagener, Norbert (2017). Seeverkehrswirtschaft: Kompendium. De Gruyter: Berlin/Boston</li> <li>• Böse, Jürgen W. (2020). Handbook of Terminal Planning. Springer: New York</li> <li>• Jahn, Carlos and Saxe, Sebastian (2017). Digitalization of Seaports - Visions of the Future. Fraunhofer Verlag: Stuttgart</li> <li>• Kummer, Sebastian (2019). Einführung in die Verkehrswirtschaft. UTB: Stuttgart and s.l.</li> <li>• Mi, Weijian and Liu, Yuan (2022). Smart Ports. Springer: Singapore</li> <li>• UNCTAD (2024). Review of Maritime Transport 2024. UN: United Nations Publications, New York, USA</li> <li>• Zhang, Xufan and Roe, Michael (2019). Maritime Container Port Security. Palgrave Macmillan Cham: Basingstoke</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

| Course L1473: Port Logistics |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                   | Recitation Section (small)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Hrs/wk</b>                | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>CP</b>                    | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Workload in Hours</b>     | Independent Study Time 62, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Lecturer</b>              | Prof. Carlos Jahn                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Language</b>              | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Cycle</b>                 | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Content</b>               | <p>The content of the exercise is the independent preparation of a scientific paper plus an accompanying presentation on a current topic of port logistics. The paper deals with current topics of port logistics. For example, the future challenges in sustainability and productivity of ports, the digital transformation of terminals and ports or the introduction of new regulations by the International Maritime Organization regarding the verified gross weight of containers. Due to the international orientation of the event, the paper is to be prepared in English.</p>                                                                                                                                                                                                                                        |
| <b>Literature</b>            | <ul style="list-style-type: none"> <li>• Biebig, Peter and Althof, Wolfgang and Wagener, Norbert (2017). Seeverkehrswirtschaft: Kompendium. De Gruyter: Berlin/Boston</li> <li>• Böse, Jürgen W. (2020). Handbook of Terminal Planning. Springer: New York</li> <li>• Jahn, Carlos and Saxe, Sebastian (2017). Digitalization of Seaports - Visions of the Future. Fraunhofer Verlag: Stuttgart</li> <li>• Kummer, Sebastian (2019). Einführung in die Verkehrswirtschaft. UTB: Stuttgart and s.l.</li> <li>• Mi, Weijian and Liu, Yuan (2022). Smart Ports. Springer: Singapore</li> <li>• UNCTAD (2024). Review of Maritime Transport 2024. UN: United Nations Publications, New York, USA</li> <li>• Zhang, Xufan and Roe, Michael (2019). Maritime Container Port Security. Palgrave Macmillan Cham: Basingstoke</li> </ul> |

| Module M1132: Maritime Transport                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |                |             |                                                                             |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|----------------|-------------|-----------------------------------------------------------------------------|
| Courses                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |                |             |                                                                             |
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Typ                        |                | Hrs/wk      | CP                                                                          |
| Maritime Transport (L0063)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Lecture                    |                | 2           | 3                                                                           |
| Maritime Transport (L0064)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Recitation Section (small) |                | 2           | 3                                                                           |
| Module Responsible                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Prof. Carlos Jahn                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                            |                |             |                                                                             |
| Admission Requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |                |             |                                                                             |
| Recommended Previous Knowledge                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |                |             |                                                                             |
| Educational Objectives                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |                |             |                                                                             |
| Professional Competence                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | <div><div>Knowledge</div><div>The students are able to...<ul style="list-style-type: none"><li>• present the actors involved in the maritime transport chain with regard to their typical tasks;</li><li>• name common cargo types in shipping and classify cargo to the corresponding categories;</li><li>• explain operating forms in maritime shipping, transport options and management in transport networks;</li><li>• weigh the advantages and disadvantages of the various modes of hinterland transport and apply them in practice;</li><li>• estimate the potential of digitisation in maritime shipping.</li></ul></div><div>Skills</div><div>The students are able to...<ul style="list-style-type: none"><li>• determine the mode of transport, actors and functions of the actors in the maritime supply chain;</li><li>• identify possible cost drivers in a transport chain and recommend appropriate proposals for cost reduction;</li><li>• record, map and systematically analyse material and information flows of a maritime logistics chain, identify possible problems and recommend solutions;</li><li>• perform risk assessments of human disruptions to the supply chain;</li><li>• analyse accidents in the field of maritime logistics and evaluating their relevance in everyday life;</li><li>• deal with current research topics in the field of maritime logistics in a differentiated way;</li><li>• plan the deployment of a fleet based on scenarios;</li><li>• apply different process modelling methods in a hitherto unknown field of activity and to work out the respective advantages.</li></ul></div></div> |                            |                |             |                                                                             |
| Personal Competence                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |                |             |                                                                             |
| <div><div>Social Competence</div><div>The students are able to...<ul style="list-style-type: none"><li>• discuss and organise extensive work packages in groups;</li><li>• document and present the elaborated results.</li></ul></div><div>Autonomy</div><div>The students are capable to...<ul style="list-style-type: none"><li>• research and select technical literature, including standards and guidelines;</li><li>• submit own shares in an extensive written elaboration in small groups in due time.</li></ul></div></div> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |                |             |                                                                             |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |                |             |                                                                             |
| Workload in Hours                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Independent Study Time 124, Study Time in Lecture 56                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |                |             |                                                                             |
| Credit points                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                            |                |             |                                                                             |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Bonus                      | Form           | Description |                                                                             |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | No                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 15 %                       | Subject        | theoretical | andTeilnahme an einem Planspiel und anschließende schriftliche Ausarbeitung |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            | practical work |             |                                                                             |
| Examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                            |                |             |                                                                             |
| Examination duration and scale                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 120 minutes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                            |                |             |                                                                             |
| Assignment for the Following Curricula                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Logistics: Elective Compulsory<br>Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory<br>Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory<br>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Maritime Technology: Elective Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                            |                |             |                                                                             |

| Course L0063: Maritime Transport |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                       | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Hrs/wk</b>                    | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>CP</b>                        | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Workload in Hours</b>         | Independent Study Time 62, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Lecturer</b>                  | Prof. Carlos Jahn                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Language</b>                  | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Cycle</b>                     | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Content</b>                   | <p>The general tasks of maritime logistics include the planning, design, implementation and control of material and information flows in the logistics chain ship - port - hinterland. The aim of the course is to provide students with knowledge of maritime transport and the actors involved in the maritime transport chain. Typical problem areas and tasks will be dealt with, taking into account the economic development. Thus, classical problems as well as current developments and trends in the field of maritime logistics are considered.</p> <p>In the lecture, the components of the maritime logistics chain and the actors involved will be examined and risk assessments of human disturbances on the supply chain will be developed. In addition, students learn to estimate the potential of digitisation in maritime shipping, especially with regard to the monitoring of ships. In addition, students are able to design operational planning for fleets of container or tramp vessels. Further content of the lecture is the different modes of transport in the hinterland, which students can evaluate after completion of the course regarding their advantages and disadvantages.</p> |
| <b>Literature</b>                | <ul style="list-style-type: none"> <li>Rodrigue, Jean-Paul. Geography of Transport Systems. London New York: Routledge, 2020.</li> <li>Geisler, Alexander and Johns, Dirk Max (2018). SEE-SCHIFF-LADUNG: Fachbuch für Schifffahrtskaufleute : von Praktikern für Praktiker. von Stern-Verlag KG: Lüneburg.</li> <li>Huber, Wolfgang (2018). Überseecontainer beladen. Verlag Heinrich Vogel.</li> <li>Jensen, Rune Møller and Pacino, Dario and Ajspur, Mai Lise and Vesterdal, Claus (2018). Container vessel stowage planning. Weilbach.</li> <li>UNCTAD (2024). Review of Maritime Transport 2024. UN: United Nations Publications, New York, USA.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

| Course L0064: Maritime Transport |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                       | Recitation Section (small)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Hrs/wk</b>                    | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>CP</b>                        | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Workload in Hours</b>         | Independent Study Time 62, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Lecturer</b>                  | Prof. Carlos Jahn                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Language</b>                  | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Cycle</b>                     | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Content</b>                   | <p>The exercise lesson bases on the haptic management game MARITIME. MARITIME focuses on providing knowledge about structures and processes in a maritime transport network. Furthermore, the management game systematically provides process management methodology and also promotes personal skills of the participants.</p>                                                                                                                                                                                                                            |
| <b>Literature</b>                | <ul style="list-style-type: none"> <li>Brinkmann, Birgitt. Seehäfen: Planung und Entwurf. Berlin Heidelberg: Springer-Verlag, 2005.</li> <li>Böse, Jürgen W. Handbook of Terminal Planning. Springer, Cham, 2020.</li> <li>Lieberuth, Thomas. Prozessmanagement in Einkauf und Logistik - Instrumente und Methoden für das Supply Chain Process Management, Springer Gabler Wiesbaden, 2024.</li> <li>Laue, Ralf; Koschmider, Agnes; Fahland, Dirk. Prozessmanagement und Process-Mining: Grundlagen, Walter de Gruyter GmbH &amp; Co KG, 2020.</li> </ul> |

| Module M1343: Structure and properties of fibre-polymer-composites |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                 |        |    |
|--------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|--------|----|
| Courses                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                 |        |    |
| Title                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Typ                             | Hrs/wk | CP |
| Structure and properties of fibre-polymer-composites (L1894)       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Lecture                         | 2      | 3  |
| Structure and properties of fibre-polymer-composites (L2614)       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Project-/problem-based Learning | 2      | 2  |
| Structure and properties of fibre-polymer-composites (L2613)       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Recitation Section (large)      | 1      | 1  |
| Module Responsible                                                 | Prof. Bodo Fiedler                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                 |        |    |
| Admission Requirements                                             | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                 |        |    |
| Recommended Previous Knowledge                                     | Basics: chemistry / physics / materials science                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                 |        |    |
| Educational Objectives                                             | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                 |        |    |
| <b>Professional Competence</b><br><i>Knowledge</i>                 | Students can use the knowledge of fiber-reinforced composites (FRP) and its constituents to play (fiber / matrix) and define the necessary testing and analysis.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                 |        |    |
|                                                                    | They can explain the complex relationships structure-property relationship and                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                 |        |    |
|                                                                    | the interactions of chemical structure of the polymers, their processing with the different fiber types, including to explain neighboring contexts (e.g. sustainability, environmental protection).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                 |        |    |
| <i>Skills</i>                                                      | Students are capable of                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                 |        |    |
|                                                                    | <ul style="list-style-type: none"><li>• using standardized calculation methods in a given context to mechanical properties (modulus, strength) to calculate and evaluate the different materials.</li><li>• approximate sizing using the network theory of the structural elements implement and evaluate.</li><li>• selecting appropriate solutions for mechanical recycling problems and sizing example stiffness, corrosion resistance.</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                 |        |    |
| <b>Personal Competence</b><br><i>Social Competence</i>             | Students can                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                 |        |    |
|                                                                    | <ul style="list-style-type: none"><li>• arrive at funded work results in heterogenius groups and document them.</li><li>• provide appropriate feedback and handle feedback on their own performance constructively.</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                 |        |    |
| <i>Autonomy</i>                                                    | Students are able to                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                 |        |    |
|                                                                    | <ul style="list-style-type: none"><li>- assess their own strengths and weaknesses.</li><li>- assess their own state of learning in specific terms and to define further work steps on this basis.</li><li>- assess possible consequences of their professional activity.</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                 |        |    |
| Workload in Hours                                                  | Independent Study Time 110, Study Time in Lecture 70                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                 |        |    |
| Credit points                                                      | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                 |        |    |
| Course achievement                                                 | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                 |        |    |
| Examination                                                        | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                 |        |    |
| Examination duration and scale                                     | 90 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                 |        |    |
| Assignment for the Following Curricula                             | Aircraft Systems Engineering: Core Qualification: Elective Compulsory<br>International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory<br>Aeronautics: Core Qualification: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Specialisation Product Development: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Specialisation Production: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Specialisation Materials: Compulsory<br>Materials Science and Engineering: Specialisation Engineering Materials: Elective Compulsory<br>Mechanical Engineering and Management: Core Qualification: Compulsory<br>Biomedical Engineering: Specialisation Implants and Endoprotheses: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Production: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Materials: Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Materials Science: Elective Compulsory |                                 |        |    |

| Course L1894: Structure and properties of fibre-polymer-composites |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|--------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                         | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Hrs/wk</b>                                                      | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>CP</b>                                                          | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Workload in Hours</b>                                           | Independent Study Time 62, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Lecturer</b>                                                    | Prof. Bodo Fiedler                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Language</b>                                                    | EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Cycle</b>                                                       | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Content</b>                                                     | <ul style="list-style-type: none"> <li>- Microstructure and properties of the matrix and reinforcing materials and their interaction</li> <li>- Development of composite materials</li> <li>- Mechanical and physical properties</li> <li>- Mechanics of Composite Materials</li> <li>- Laminate theory</li> <li>- Test methods</li> <li>- Non destructive testing</li> <li>- Failure mechanisms</li> <li>- Theoretical models for the prediction of properties</li> <li>- Application</li> </ul> |
| <b>Literature</b>                                                  | Hall, Clyne: Introduction to Composite materials, Cambridge University Press<br>Daniel, Ishai: Engineering Mechanics of Composites Materials, Oxford University Press<br>Mallick: Fibre-Reinforced Composites, Marcel Dekker, New York                                                                                                                                                                                                                                                            |

| Course L2614: Structure and properties of fibre-polymer-composites |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|--------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                         | Project-/problem-based Learning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Hrs/wk</b>                                                      | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>CP</b>                                                          | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Workload in Hours</b>                                           | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Lecturer</b>                                                    | Prof. Bodo Fiedler                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Language</b>                                                    | DE/EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Cycle</b>                                                       | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Content</b>                                                     | <p>The students receive the assignment in the form of a material design for test bodies made of fibre composites. Technical and normative requirements are listed in the assignment, all other required information comes from the lectures and exercises or the respective documents (electronically and in conversation).</p> <p>The procedure is specified in a milestone plan and enables the students to plan subtasks and thus work continuously. At the end of the project, different test specimens were tested in tensile or bending tests.</p> <p>In the individual project meetings, the conception (discussion of requirements and risks) is scrutinised. The calculations are analysed, the production methods are evaluated and determined. Materials are selected and the test specimens are manufactured according to standards. The quality and mechanical properties are checked and classified. At the end, a final report is prepared and the results are presented to all participants in the form of a presentation and discussed.</p> <p>Translated with <a href="https://www.DeepL.com/Translator">www.DeepL.com/Translator</a> (free version)</p> |
| <b>Literature</b>                                                  | Hall, Clyne: Introduction to Composite materials, Cambridge University Press<br>Daniel, Ishai: Engineering Mechanics of Composites Materials, Oxford University Press<br>Mallick: Fibre-Reinforced Composites, Marcel Dekker, New York                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

| Course L2613: Structure and properties of fibre-polymer-composites |                                                                                                                                                                                                                                        |
|--------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                         | Recitation Section (large)                                                                                                                                                                                                             |
| <b>Hrs/wk</b>                                                      | 1                                                                                                                                                                                                                                      |
| <b>CP</b>                                                          | 1                                                                                                                                                                                                                                      |
| <b>Workload in Hours</b>                                           | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                    |
| <b>Lecturer</b>                                                    | Prof. Bodo Fiedler                                                                                                                                                                                                                     |
| <b>Language</b>                                                    | EN                                                                                                                                                                                                                                     |
| <b>Cycle</b>                                                       | SoSe                                                                                                                                                                                                                                   |
| <b>Content</b>                                                     | <p>The contents of the lecture are repeated and deepened using practical examples.</p> <p>Calculations are carried out together or individually, and the results are discussed critically.</p>                                         |
| <b>Literature</b>                                                  | Hall, Clyne: Introduction to Composite materials, Cambridge University Press<br>Daniel, Ishai: Engineering Mechanics of Composites Materials, Oxford University Press<br>Mallick: Fibre-Reinforced Composites, Marcel Dekker, New York |

| Module M1709: Applied Optimization in Energy and Process Engineering |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |              |             |                    |
|----------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|-------------|--------------------|
| Courses                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |              |             |                    |
| Title                                                                | Typ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |              | Hrs/wk      | CP                 |
| Applied optimization in energy and process engineering (L2693)       | Integrated Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |              | 2           | 3                  |
| Applied optimization in energy and process engineering (L2695)       | Recitation Section (small)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |              | 3           | 3                  |
| <b>Module Responsible</b>                                            | Prof. Mirko Skiborowski                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |              |             |                    |
| <b>Admission Requirements</b>                                        | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |              |             |                    |
| <b>Recommended Previous Knowledge</b>                                | <p>Fundamentals in the field of mathematical modeling and numerical mathematics, as well as a basic understanding of process engineering processes.</p> <p>In particular the contents of the module Process and Plant Engineering II</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |              |             |                    |
| <b>Educational Objectives</b>                                        | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |              |             |                    |
| <b>Professional Competence</b><br><i>Knowledge</i>                   | <p>The module provides a general introduction to the basics of applied mathematical optimization and deals with application areas on different scales from the identification of kinetic models, to the optimal design of unit operations and the optimization of entire (sub)processes, as well as production planning. In addition to the basic classification and formulation of optimization problems, different solution approaches are discussed and tested during the exercises. Besides deterministic gradient-based methods, metaheuristics such as evolutionary and genetic algorithms and their application are discussed as well.</p> <ul style="list-style-type: none"> <li>• Introduction to Applied Optimization</li> <li>• Formulation of optimization problems</li> <li>• Linear Optimization</li> <li>• Nonlinear Optimization</li> <li>• Mixed-integer (non)linear optimization</li> <li>• Multi-objective optimization</li> <li>• Global optimization</li> </ul>                                                                                                                                                                                   |              |             |                    |
| <i>Skills</i>                                                        | <p>After successful participation in the module "Applied Optimization in Energy and Process Engineering", students are able to formulate the different types of optimization problems and to select appropriate solution methods in suitable software such as Matlab and GAMS and to develop improved solution strategies. Furthermore, students will be able to interpret and critically examine the results accordingly.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |              |             |                    |
| <b>Personal Competence</b><br><i>Social Competence</i>               | <p>Students are capable of:</p> <ul style="list-style-type: none"> <li>• develop solutions in heterogeneous small groups</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |              |             |                    |
| <i>Autonomy</i>                                                      | <p>Students are capable of:</p> <ul style="list-style-type: none"> <li>• tapping new knowledge on a special subject by literature research</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |              |             |                    |
| <b>Workload in Hours</b>                                             | Independent Study Time 110, Study Time in Lecture 70                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |              |             |                    |
| <b>Credit points</b>                                                 | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |              |             |                    |
| <b>Course achievement</b>                                            | <b>Compulsory</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <b>Bonus</b> | <b>Form</b> | <b>Description</b> |
|                                                                      | No                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 10 %         | Midterm     | Bonuspunkte        |
| <b>Examination</b>                                                   | Oral exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |              |             |                    |
| <b>Examination duration and scale</b>                                | 35 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |              |             |                    |
| <b>Assignment for the Following Curricula</b>                        | <p>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory</p> <p>Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory</p> <p>Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory</p> <p>Computational Methods and Machine Learning in Engineering: Core Qualification: Elective Compulsory</p> <p>Energy Systems: Specialisation Energy Systems: Elective Compulsory</p> <p>Environmental Engineering: Specialisation Energy and Resources: Elective Compulsory</p> <p>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory</p> <p>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory</p> <p>Technomathematics: Specialisation III. Engineering Science: Elective Compulsory</p> <p>Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory</p> <p>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory</p> <p>Process Engineering: Specialisation Process Engineering: Elective Compulsory</p> |              |             |                    |



| Course L2693: Applied optimization in energy and process engineering |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|----------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                           | Integrated Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Hrs/wk</b>                                                        | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>CP</b>                                                            | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Workload in Hours</b>                                             | Independent Study Time 62, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Lecturer</b>                                                      | Prof. Mirko Skiborowski                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Language</b>                                                      | EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Cycle</b>                                                         | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Content</b>                                                       | <p>The lecture offers a general introduction to the basics and possibilities of applied mathematical optimization and deals with application areas on different scales from kinetics identification, optimal design of unit operations to the optimization of entire (sub)processes, and production planning. In addition to the basic classification and formulation of optimization problems, different solution approaches are discussed. Besides deterministic gradient-based methods, metaheuristics such as evolutionary and genetic algorithms and their application are discussed as well.</p> <ul style="list-style-type: none"> <li>- Introduction to Applied Optimization</li> <li>- Formulation of optimization problems</li> <li>- Linear Optimization</li> <li>- Nonlinear Optimization</li> <li>- Mixed-integer (non)linear optimization</li> <li>- Multi-objective optimization</li> <li>- Global optimization</li> </ul> |
| <b>Literature</b>                                                    | <p>Weicker, K., Evolutionäre Algorithmen, Springer, 2015</p> <p>Edgar, T. F., Himmelblau D. M., Lasdon, L. S., Optimization of Chemical Processes, McGraw Hill, 2001</p> <p>Biegler, L. Nonlinear Programming - Concepts, Algorithms, and Applications to Chemical Processes, 2010</p> <p>Kallrath, J. Gemischt-ganzzahlige Optimierung: Modellierung in der Praxis, Vieweg, 2002</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

| Course L2695: Applied optimization in energy and process engineering |                                                     |
|----------------------------------------------------------------------|-----------------------------------------------------|
| <b>Typ</b>                                                           | Recitation Section (small)                          |
| <b>Hrs/wk</b>                                                        | 3                                                   |
| <b>CP</b>                                                            | 3                                                   |
| <b>Workload in Hours</b>                                             | Independent Study Time 48, Study Time in Lecture 42 |
| <b>Lecturer</b>                                                      | Prof. Mirko Skiborowski                             |
| <b>Language</b>                                                      | EN                                                  |
| <b>Cycle</b>                                                         | SoSe                                                |
| <b>Content</b>                                                       | See interlocking course                             |
| <b>Literature</b>                                                    | See interlocking course                             |

| Module M2109: Risk Management, Hydrogentechnology and Energy Trading |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |    |
|----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|----|
| Courses                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |    |
| Title                                                                | Typ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Hrs/wk | CP |
| Energy Trading (L0019)                                               | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1      | 1  |
| Energy Trading (L0020)                                               | Recitation Section (small)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1      | 1  |
| Risk Management in the Energy Industry (L1748)                       | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2      | 2  |
| Hydrogen Technology (L0060)                                          | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2      | 2  |
| Module Responsible                                                   | Prof. Martin Kaltschmitt                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |        |    |
| Admission Requirements                                               | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |        |    |
| Recommended Previous Knowledge                                       | none                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |        |    |
| Educational Objectives                                               | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |        |    |
| Professional Competence                                              | <div>Knowledge</div> <p>With completion of this module students can explain basics of risk management involving thematical adjacent contexts and can describe an optimal management of energy systems.</p> <p>Furthermore, students can reproduce solid theoretical knowledge about the potentials and applications of new information technologies in logistics and explain technical aspects of the use, production and processing of hydrogen.</p> <div>Skills</div> <p>With completion of this module students are able to evaluate risks of energy systems with respect to energy economic conditions in an efficient way. This includes that the students can assess the risks in operational planning of power plants from a technical, economic and ecological perspective.</p> <p>In this context, students can evaluate the potentials of logistics and information technology in particular on energy issues.</p> <p>In addition, students are able to describe the energy transfer medium hydrogen according to its applications, the given security and its existing service capacities and limits as well as to evaluate these aspects from a technical, environmental and economic perspective.</p> <div>Personal Competence</div> <div>Social Competence</div> <p>Students are able to discuss issues in the thematic fields in the renewable energy sector addressed within the module.</p> <div>Autonomy</div> <p>Students can independently exploit sources on the emphasis of the lectures and acquire the contained knowledge. In this way, they can recognize their lacks of knowledge and can consequently define the further workflow.</p> |        |    |
|                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |    |
|                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |    |
|                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |    |
|                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |        |    |
| Workload in Hours                                                    | Independent Study Time 96, Study Time in Lecture 84                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |        |    |
| Credit points                                                        | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |        |    |
| Course achievement                                                   | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |        |    |
| Examination                                                          | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |        |    |
| Examination duration and scale                                       | 180 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |        |    |
| Assignment for the Following Curricula                               | Aircraft Systems Engineering: Core Qualification: Elective Compulsory<br>Aeronautics: Core Qualification: Elective Compulsory<br>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |        |    |

| Course L0019: Energy Trading |                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Type</b>                  | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Hrs/wk</b>                | 1                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>CP</b>                    | 1                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Workload in Hours</b>     | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Lecturer</b>              | Robert Gersdorf                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Language</b>              | DE                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Cycle</b>                 | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Content</b>               | <ul style="list-style-type: none"> <li>• Basic concepts and tradable products in energy markets</li> <li>• Primary energy markets</li> <li>• Electricity Markets</li> <li>• European Emissions Trading Scheme</li> <li>• Influence of renewable energy</li> <li>• Real options</li> <li>• Risk management</li> </ul> <p>Within the exercise the various tasks are actively discussed and applied to various cases of application.</p> |
| <b>Literature</b>            |                                                                                                                                                                                                                                                                                                                                                                                                                                       |

| Course L0020: Energy Trading |                                                     |
|------------------------------|-----------------------------------------------------|
| <b>Typ</b>                   | Recitation Section (small)                          |
| <b>Hrs/wk</b>                | 1                                                   |
| <b>CP</b>                    | 1                                                   |
| <b>Workload in Hours</b>     | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>              | Robert Gersdorf                                     |
| <b>Language</b>              | DE                                                  |
| <b>Cycle</b>                 | SoSe                                                |
| <b>Content</b>               | See interlocking course                             |
| <b>Literature</b>            | See interlocking course                             |

| Course L1748: Risk Management in the Energy Industry |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                           | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Hrs/wk</b>                                        | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>CP</b>                                            | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Workload in Hours</b>                             | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Lecturer</b>                                      | Dr. Christian Wulf                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Language</b>                                      | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Cycle</b>                                         | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Content</b>                                       | <ul style="list-style-type: none"> <li>• Basics of risk management <ul style="list-style-type: none"> <li>◦ Definition of terms</li> <li>◦ Risk types</li> <li>◦ Risk management process</li> <li>◦ Enterprise risk management</li> </ul> </li> <li>• Markets and instruments in energy trading <ul style="list-style-type: none"> <li>◦ Basics of futures and spot trading</li> <li>◦ Notation in energy markets</li> <li>◦ Options</li> </ul> </li> <li>• Kennzahlendefinition <ul style="list-style-type: none"> <li>◦ Assessing of market risks</li> <li>◦ Assessing of credit risks</li> <li>◦ Assessing of operational risks</li> <li>◦ Assessing of liquidity risks</li> </ul> </li> <li>• Risk monitoring and reporting</li> <li>• Risk treatment</li> </ul> |
| <b>Literature</b>                                    | <ul style="list-style-type: none"> <li>• Roggi, O. (2012): Risk Taking: A Corporate Governance Perspective, International Finance Corporation, New York</li> <li>• Hull, J. C. (2012): Options, Futures, and other Derivatives, 8. Auflage, Pearson Verlag, New York</li> <li>• Albrecht, P.; Maurer, R. (2008): Investment- und Risikomanagement, 3. Auflage, Schäffer-Poeschel Verlag, Stuttgart</li> <li>• Rittenberg, L.; Martens, F. (2012): Understanding and Communicating Risk Appetite, Treadway Commission, Durham</li> </ul>                                                                                                                                                                                                                              |

| Course L0060: Hydrogen Technology |                                                                                                                                                                                                                                                                                                                                                                          |
|-----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                        | Lecture                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Hrs/wk</b>                     | 2                                                                                                                                                                                                                                                                                                                                                                        |
| <b>CP</b>                         | 2                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Workload in Hours</b>          | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                      |
| <b>Lecturer</b>                   | Dr. Jose Bellosta von Colbe, Dr. Paul Jerabek                                                                                                                                                                                                                                                                                                                            |
| <b>Language</b>                   | DE                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Cycle</b>                      | SoSe                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Content</b>                    | <ol style="list-style-type: none"> <li>1. Energy economy</li> <li>2. Hydrogen economy</li> <li>3. Occurrence and properties of hydrogen</li> <li>4. Production of hydrogen (from hydrocarbons and by electrolysis)</li> <li>5. Separation and purification Storage and transport of hydrogen</li> <li>6. Security</li> <li>7. Fuel cells</li> <li>8. Projects</li> </ol> |
| <b>Literature</b>                 | <ul style="list-style-type: none"> <li>• Skriptum zur Vorlesung</li> <li>• Winter, Nitsch: Wasserstoff als Energieträger</li> <li>• Ullmann's Encyclopedia of Industrial Chemistry</li> <li>• Kirk, Othmer: Encyclopedia of Chemical Technology</li> <li>• Larminie, Dicks: Fuel cell systems explained</li> </ul>                                                       |

| Module M2139: District Heating         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |        |    |
|----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|----|
| Courses                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |        |    |
| Title                                  | Typ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Hrs/wk | CP |
| Combined Heat and Power (CHP) (L3430)  | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 2      | 2  |
| Pipeline-based Heat Supply (L3428)     | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 2      | 2  |
| Heat from Deep Geothermal Heat (L3429) | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 2      | 2  |
| Module Responsible                     | Prof. Arne Speerforck                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |        |    |
| Admission Requirements                 | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |        |    |
| Recommended Previous Knowledge         | Technical Thermodynamics I, II, Fluid Dynamics, Heat Transfer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |        |    |
| Educational Objectives                 | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |        |    |
| Professional Competence                | <p><i>Knowledge</i> Students are familiar with the technical fundamentals of energy conversion in combined heat and power plants, as well as the conduction-based heat transport and the utilization of deep geothermal energy. They are knowledgeable about the structure and content of relevant technical regulations. They can distinguish between various plant configurations, understand fundamental characteristics, and identify the advantages and disadvantages of different solutions. They are aware of current challenges and can categorize, develop, and evaluate transformation paths for different district heating systems.</p> <p><i>Skills</i> Students are capable of designing district heating networks and sizing the corresponding plant technology. They can apply calculation methods and technical regulations. They are able to quantify the potential of deep geothermal energy and calculate systems for combined heat and power. They can assess transformation paths for district heating networks and follow public discourse on the heat transition.</p> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> The students can engage in goal-oriented discussions in small groups using various examples and thought experiments, develop a solution approach, and present it. They are able to independently formulate more in-depth questions within the framework of exercises and work out targeted solutions.</p> <p><i>Autonomy</i> Students are able to independently define tasks, develop the necessary knowledge based on the acquired knowledge, and use appropriate tools to implement them. In the exercises, students discuss the methods taught in the lectures using complex problems and critically analyze the results.</p> |        |    |
|                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |        |    |
|                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |        |    |
|                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |        |    |
| Workload in Hours                      | Independent Study Time 96, Study Time in Lecture 84                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |        |    |
| Credit points                          | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |        |    |
| Course achievement                     | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |        |    |
| Examination                            | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |        |    |
| Examination duration and scale         | 180 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |        |    |
| Assignment for the Following Curricula | Energy Systems: Specialisation Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |        |    |

| Course L3430: Combined Heat and Power (CHP) |                                                     |
|---------------------------------------------|-----------------------------------------------------|
| Typ                                         | Lecture                                             |
| Hrs/wk                                      | 2                                                   |
| CP                                          | 2                                                   |
| Workload in Hours                           | Independent Study Time 32, Study Time in Lecture 28 |
| Lecturer                                    | Dr. Kristin Abel-Günther                            |
| Language                                    | DE                                                  |
| Cycle                                       | SoSe                                                |
| Content                                     |                                                     |
| Literature                                  |                                                     |

| Course L3428: Pipeline-based Heat Supply |                                                     |
|------------------------------------------|-----------------------------------------------------|
| Typ                                      | Lecture                                             |
| Hrs/wk                                   | 2                                                   |
| CP                                       | 2                                                   |
| Workload in Hours                        | Independent Study Time 32, Study Time in Lecture 28 |
| Lecturer                                 | NN                                                  |
| Language                                 | DE                                                  |
| Cycle                                    | SoSe                                                |
| Content                                  |                                                     |
| Literature                               |                                                     |

| Course L3429: Heat from Deep Geothermal Heat |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|----------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                   | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Hrs/wk</b>                                | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>CP</b>                                    | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Workload in Hours</b>                     | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Lecturer</b>                              | Dr. Ben Norden                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Language</b>                              | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Cycle</b>                                 | SoSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Content</b>                               | <ol style="list-style-type: none"> <li>1. Geological Background</li> <li>2. Hydrothermal targets for geothermal and aquifer storage applications</li> <li>3. Exploration and petrophysics supporting geothermal planning and site development</li> <li>4. Geological modeling and usage cases</li> </ol>                                                                                                                                                                                                                                                |
| <b>Literature</b>                            | <ul style="list-style-type: none"> <li>• Kaltschmitt et al. (eds): Erneuerbare Energien: Systemtechnik, Wirtschaftlichkeit, Umweltaspekte. Springer, 6. Aufl. 2020.</li> <li>• Livescu, S. &amp; Dindoruk, B (eds): Geothermal Energy Engineering, Elsevier, 2025.</li> <li>• Bloemendal, M. et al., 2014: How to achieve optimal and sustainable use of the subsurface for Aquifer Thermal Energy Storage, Energy Policy, Volume 66, <a href="https://doi.org/10.1016/j.enpol.2013.11.034">https://doi.org/10.1016/j.enpol.2013.11.034</a>.</li> </ul> |

| Module M0528: Maritime Technology and Offshore Wind Parks                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |               |           |
|--------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|-----------|
| Courses                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |               |           |
| <b>Title</b>                                                                               | <b>Typ</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <b>Hrs/wk</b> | <b>CP</b> |
| Introduction to Maritime Technology (L0070)                                                | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2             | 2         |
| Introduction to Maritime Technology (L1614)                                                | Recitation Section (small)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 1             | 1         |
| Offshore Wind Parks (L0072)                                                                | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2             | 3         |
| <b>Module Responsible</b>                                                                  | Prof. Moustafa Abdel-Maksoud                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |               |           |
| <b>Admission Requirements</b>                                                              | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |               |           |
| <b>Recommended Previous Knowledge</b>                                                      | <p>Qualified Bachelor of a natural or engineering science; Solid knowledge and competences in mathematics, mechanics, fluid dynamics.</p> <p>Basic knowledge of ocean engineering topics (e.g. from an introductory class like 'Introduction to Maritime Technology')</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |               |           |
| <b>Educational Objectives</b>                                                              | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |               |           |
| <b>Professional Competence</b><br><i>Knowledge</i>                                         | <p>After successful completion of this class, students should have an overview about phenomena and methods in ocean engineering and the ability to apply and extend the methods presented. In detail, the students should be able to</p> <ul style="list-style-type: none"> <li>describe the different aspects and topics in Maritime Technology,</li> <li>apply existing methods to problems in Maritime Technology,</li> <li>discuss limitations in present day approaches and perspectives in the future.</li> </ul> <p>Based on research topics of present relevance the participants are to be prepared for independent research work in the field. For that purpose specific research problems of workable scope will be addressed in the class.</p> <p>After successful completion of this module, students should be able to</p> <ul style="list-style-type: none"> <li>Show present research questions in the field</li> <li>Explain the present state of the art for the topics considered</li> <li>Apply given methodology to approach given problems</li> <li>Evaluate the limits of the present methods</li> <li>Identify possibilities to extend present methods</li> <li>Evaluate the feasibility of further developments</li> </ul> |               |           |
| <b>Personal Competence</b><br><i>Skills</i><br><i>Social Competence</i><br><i>Autonomy</i> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |               |           |
| <b>Workload in Hours</b>                                                                   | Independent Study Time 110, Study Time in Lecture 70                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |               |           |
| <b>Credit points</b>                                                                       | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |               |           |
| <b>Course achievement</b>                                                                  | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |               |           |
| <b>Examination</b>                                                                         | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |               |           |
| <b>Examination duration and scale</b>                                                      | 180 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |               |           |
| <b>Assignment for the Following Curricula</b>                                              | <p>Energy Systems: Specialisation Marine Engineering: Elective Compulsory</p> <p>Energy Systems: Specialisation Green Energy Technologies: Elective Compulsory</p> <p>International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory</p> <p>International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory</p> <p>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |               |           |

| Course L0070: Introduction to Maritime Technology |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|---------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                        | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Hrs/wk</b>                                     | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>CP</b>                                         | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Workload in Hours</b>                          | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Lecturer</b>                                   | Dr. Walter Kuehnlein                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Language</b>                                   | DE/EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Cycle</b>                                      | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Content</b>                                    | <p>1. Introduction</p> <ul style="list-style-type: none"> <li>• Ocean Engineering and Marine Research</li> <li>• The potentials of the seas</li> <li>• Industries and occupational structures</li> </ul> <p>2. Coastal and offshore Environmental Conditions</p> <ul style="list-style-type: none"> <li>• Physical and chemical properties of sea water and sea ice</li> <li>• Flows, waves, wind, ice</li> <li>• Biosphere</li> </ul> <p>3. Response behavior of Technical Structures</p> <p>4. Maritime Systems and Technologies</p> <ul style="list-style-type: none"> <li>• General Design and Installation of Offshore-Structures</li> <li>• Geophysical and Geotechnical Aspects</li> <li>• Fixed and Floating Platforms</li> <li>• Mooring Systems, Risers, Pipelines</li> <li>• Energy conversion: Wind, Waves, Tides</li> </ul> |
| <b>Literature</b>                                 | <ul style="list-style-type: none"> <li>• Chakrabarti, S., Handbook of Offshore Engineering, vol. I/II, Elsevier 2005.</li> <li>• Gerwick, B.C., Construction of Marine and Offshore Structures, CRC-Press 1999.</li> <li>• Wagner, P., Meerestechnik, Ernst&amp;Sohn 1990.</li> <li>• Clauss, G., Meerestechnische Konstruktionen, Springer 1988.</li> <li>• Knauss, J.A., Introduction to Physical Oceanography, Waveland 2005.</li> <li>• Wright, J. et al., Waves, Tides and Shallow-Water Processes, Butterworth 2006.</li> <li>• Faltinsen, O.M., Sea Loads on Ships and Offshore Structures, Cambridge 1999.</li> </ul>                                                                                                                                                                                                            |

| Course L1614: Introduction to Maritime Technology |                                                     |
|---------------------------------------------------|-----------------------------------------------------|
| <b>Typ</b>                                        | Recitation Section (small)                          |
| <b>Hrs/wk</b>                                     | 1                                                   |
| <b>CP</b>                                         | 1                                                   |
| <b>Workload in Hours</b>                          | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>                                   | Dr. Walter Kuehnlein                                |
| <b>Language</b>                                   | DE/EN                                               |
| <b>Cycle</b>                                      | WiSe                                                |
| <b>Content</b>                                    | See interlocking course                             |
| <b>Literature</b>                                 | See interlocking course                             |



| Course L0072: Offshore Wind Parks |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|-----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                        | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Hrs/wk</b>                     | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>CP</b>                         | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Workload in Hours</b>          | Independent Study Time 62, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Lecturer</b>                   | Dr. Eckhard Schmidt                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Language</b>                   | DE/EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Cycle</b>                      | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Content</b>                    | <ul style="list-style-type: none"> <li>• Nonlinear Waves: Stability, pattern formation, solitary states</li> <li>• Bottom Boundary layers: wave boundary layers, scour, stability of marine slopes</li> <li>• Ice-structure interaction</li> <li>• Wave and tidal current energy conversion</li> </ul>                                                                                                                                                                                                                                                                                                                                               |
| <b>Literature</b>                 | <ul style="list-style-type: none"> <li>• Chakrabarti, S., Handbook of Offshore Engineering, vol. I&amp;II, Elsevier 2005.</li> <li>• Mc Cormick, M.E., Ocean Wave Energy Conversion, Dover 2007.</li> <li>• Infeld, E., Rowlands, G., Nonlinear Waves, Solitons and Chaos, Cambridge 2000.</li> <li>• Johnson, R.S., A Modern Introduction to the Mathematical Theory of Water Waves, Cambridge 1997.</li> <li>• Lykousis, V. et al., Submarine Mass Movements and Their Consequences, Springer 2007.</li> <li>• Nielsen, P., Coastal Bottom Boundary Layers and Sediment Transport, World Scientific 2005.</li> <li>• Research Articles.</li> </ul> |

| Module M1354: Advanced Fuels                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                            |                     |                                                             |
|--------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|---------------------|-------------------------------------------------------------|
| Courses                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                            |                     |                                                             |
| Title                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Type                       | Hrs/wk              | CP                                                          |
| Second generation biofuels and electricity based fuels (L2414)           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Lecture                    | 2                   | 2                                                           |
| Carbon dioxide as an economic determinant in the mobility sector (L1926) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Lecture                    | 1                   | 1                                                           |
| Mobility and climate protection (L2416)                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Recitation Section (small) | 2                   | 2                                                           |
| Sustainability aspects and regulatory framework (L2415)                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Lecture                    | 1                   | 1                                                           |
| Module Responsible                                                       | Dr. Marvin Scherzinger                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                            |                     |                                                             |
| Admission Requirements                                                   | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                            |                     |                                                             |
| Recommended Previous Knowledge                                           | Bachelor degree in Process Engineering, Bioprocess Engineering or Energy- and Environmental Engineering                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                            |                     |                                                             |
| Educational Objectives                                                   | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                            |                     |                                                             |
| <b>Professional Competence</b>                                           | <div><div>Knowledge</div><div>Within the module, students learn about different provision pathways for the production of advanced fuels (biofuels like e.g. alcohol-to-jet; electricity-based fuels like e.g. power-to-liquid). The different processes chains are explained and the regulatory framework for sustainable fuel production is examined. This includes, for example, the requirements of the Renewable Energies Directive II and the conditions and aspects for a market ramp-up of these fuels. For the holistic assessment of the various fuel options, they are also examined under environmental and economic factors.</div></div> <div><div>Skills</div><div>After successfully participating, the students are able to solve simulation and application tasks of renewable energy technology:<ul style="list-style-type: none"><li>Module-spanning solutions for the design and presentation of fuel production processes resp. the fuel provision chains</li><li>Comprehensive analysis of various fuel production options in technical, ecological and economic terms</li></ul></div></div> <div><div>Through active discussions of the various topics within the lectures and exercises of the module, the students improve their understanding and application of the theoretical foundations and are thus able to transfer the learned to the practice.</div></div> <div><div>Personal Competence</div><div><div>Social Competence</div><div>The students can discuss scientific tasks in a subject-specific and interdisciplinary way and develop joint solutions.</div></div><div><div>Autonomy</div><div>The students are able to access independent sources about the questions to be addressed and to acquire the necessary knowledge. They are able to assess their respective learning situation concretely in consultation with their supervisor and to define further questions and solutions.</div></div></div> |                            |                     |                                                             |
|                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                            |                     |                                                             |
|                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                            |                     |                                                             |
|                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                            |                     |                                                             |
|                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                            |                     |                                                             |
| Workload in Hours                                                        | Independent Study Time 96, Study Time in Lecture 84                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                            |                     |                                                             |
| Credit points                                                            | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |                     |                                                             |
| Course achievement                                                       | Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Bonus                      | Form                | Description                                                 |
|                                                                          | Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 20 %                       | Written elaboration | Details werden in der ersten Veranstaltung bekannt gegeben. |
| Examination                                                              | Written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |                     |                                                             |
| Examination duration and scale                                           | 120 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                            |                     |                                                             |
| Assignment for the Following Curricula                                   | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory<br>Environmental Engineering: Specialisation Energy and Resources: Elective Compulsory<br>Aircraft Systems Engineering: Core Qualification: Elective Compulsory<br>Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory<br>Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory<br>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                            |                     |                                                             |

| Course L2414: Second generation biofuels and electricity based fuels |                                                                                                                                                                                                                                                                                                |
|----------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                           | Lecture                                                                                                                                                                                                                                                                                        |
| <b>Hrs/wk</b>                                                        | 2                                                                                                                                                                                                                                                                                              |
| <b>CP</b>                                                            | 2                                                                                                                                                                                                                                                                                              |
| <b>Workload in Hours</b>                                             | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                            |
| <b>Lecturer</b>                                                      | Dr. Marvin Scherzinger                                                                                                                                                                                                                                                                         |
| <b>Language</b>                                                      | DE/EN                                                                                                                                                                                                                                                                                          |
| <b>Cycle</b>                                                         | WiSe                                                                                                                                                                                                                                                                                           |
| <b>Content</b>                                                       | <ul style="list-style-type: none"> <li>General overview of various power-based fuels and their process paths, including power-to-liquid process (Fischer-Tropsch synthesis, methanol synthesis), power-to-gas (Sabatier process)</li> <li>Origin, production and use of these fuels</li> </ul> |
| <b>Literature</b>                                                    | <ul style="list-style-type: none"> <li>Vorlesungsskript</li> </ul>                                                                                                                                                                                                                             |

| Course L1926: Carbon dioxide as an economic determinant in the mobility sector |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|--------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                                     | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Hrs/wk</b>                                                                  | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>CP</b>                                                                      | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Workload in Hours</b>                                                       | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Lecturer</b>                                                                | Dr. Karsten Wilbrand                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Language</b>                                                                | DE/EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Cycle</b>                                                                   | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Content</b>                                                                 | <ul style="list-style-type: none"> <li>General overview of various advanced biofuels and their process pathways (including gas-to-liquid, HEFA and Alcohol-to-Jet processes)</li> <li>Origin, production and use of these fuels</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Literature</b>                                                              | <ul style="list-style-type: none"> <li>Babu, V.: Biofuels Production. Beverly, Mass: Scrivener [u.a.], 2013</li> <li>Olsson, L.: Biofuels. Berlin, Heidelberg: Springer-Verlag Berlin Heidelberg, 2007</li> <li>William, L. L.: Distillation Design and Control Using Aspen Simulation; ISBN-10: 0-471-77888-5</li> <li>Perry, R.; Green, R.: Perry's Chemical Engineers' Handbook, 8th Edition, McGraw Hill Professional, 20</li> <li>Sinnott, R. K.: Chemical Engineering Design, Elsevier, 2014</li> <li>Kaltschmitt, M.; Neuling, U. (Ed.): Biokerosene - Status and Prospects; Springer, Berlin, Heidelberg, 2018</li> </ul> |

| Course L2416: Mobility and climate protection |                                                                                                                                                                                                                                                                                                                                                                                                        |
|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                    | Recitation Section (small)                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Hrs/wk</b>                                 | 2                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>CP</b>                                     | 2                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Workload in Hours</b>                      | Independent Study Time 32, Study Time in Lecture 28                                                                                                                                                                                                                                                                                                                                                    |
| <b>Lecturer</b>                               | Dr. Benedikt Buchspies, Dr. Karsten Wilbrand                                                                                                                                                                                                                                                                                                                                                           |
| <b>Language</b>                               | DE/EN                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Cycle</b>                                  | WiSe                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Content</b>                                | <p>Application of the acquired theoretical knowledge from the respective lectures on the basis of concrete tasks from practice</p> <ul style="list-style-type: none"> <li>Design and simulation of sub-processes of production processes in Aspen Plus ®</li> <li>Ecological and economic analysis of fuel supply paths</li> <li>Classification of case studies into applicable regulations</li> </ul> |
| <b>Literature</b>                             | <ul style="list-style-type: none"> <li>Skriptum zur Vorlesung</li> <li>Aspen Plus® - Aspen Plus User Guide</li> </ul>                                                                                                                                                                                                                                                                                  |

| Course L2415: Sustainability aspects and regulatory framework |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|---------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                                                    | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Hrs/wk</b>                                                 | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>CP</b>                                                     | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Workload in Hours</b>                                      | Independent Study Time 16, Study Time in Lecture 14                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Lecturer</b>                                               | Dr. Benedikt Buchspies                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Language</b>                                               | DE/EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Cycle</b>                                                  | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Content</b>                                                | <p>Holistic examination of the different fuel paths with the following main topics, among others:</p> <ul style="list-style-type: none"> <li>• Consideration of the environmental impact of the various alternative fuels</li> <li>• Economic consideration of the different alternative fuels</li> <li>• Regulatory framework for alternative fuels</li> <li>• Certification of alternative fuels</li> <li>• Market introduction models of alternative fuels</li> </ul>                      |
| <b>Literature</b>                                             | <ul style="list-style-type: none"> <li>• European Commission - Joint Research Center (2010): International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed guidance. Joint Research Center (JRC) Institut for Environment and Sustainability, Luxembourg</li> <li>• Richtlinie (EU) 2018/2001 des Europäischen Parlaments und des Rates vom 11. Dezember 2018 zur Förderung der Nutzung von Energie aus erneuerbaren Quellen</li> </ul> |

| Module M1909: System Simulation                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |               |           |
|--------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|-----------|
| <b>Courses</b>                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |               |           |
| <b>Title</b>                                                                                                                                     | <b>Typ</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>Hrs/wk</b> | <b>CP</b> |
| System Simulation Modul (L3150)                                                                                                                  | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 3             | 4         |
| System Simulation Modul (L3151)                                                                                                                  | Recitation Section (large)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2             | 2         |
| <b>Module Responsible</b>                                                                                                                        | Prof. Arne Speerforck                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |               |           |
| <b>Admission Requirements</b>                                                                                                                    | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |               |           |
| <b>Recommended Previous Knowledge</b>                                                                                                            | Mathematics I-III, Computer Science, Engineering Thermodynamics I, II, Fluid Dynamics, Heat Transfer, Control Systems                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |               |           |
| <b>Educational Objectives</b>                                                                                                                    | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |               |           |
| <b>Professional Competence</b><br><i>Knowledge</i><br><i>Skills</i><br><b>Personal Competence</b><br><i>Social Competence</i><br><i>Autonomy</i> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |               |           |
| <b>Workload in Hours</b>                                                                                                                         | Independent Study Time 110, Study Time in Lecture 70                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |               |           |
| <b>Credit points</b>                                                                                                                             | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |               |           |
| <b>Course achievement</b>                                                                                                                        | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |               |           |
| <b>Examination</b>                                                                                                                               | Oral exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |               |           |
| <b>Examination duration and scale</b>                                                                                                            | 30 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |               |           |
| <b>Assignment for the Following Curricula</b>                                                                                                    | Energy Systems: Specialisation Energy Systems: Compulsory<br>Energy Systems: Specialisation Green Energy Technologies: Elective Compulsory<br>Aircraft Systems Engineering: Core Qualification: Elective Compulsory<br>Aeronautics: Core Qualification: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Specialisation Product Development: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Specialisation Production: Elective Compulsory<br>Mechanical Engineering - Product Development and Production: Specialisation Materials: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Production: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Materials: Elective Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory |               |           |

| Course L3150: System Simulation Modul |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                            | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Hrs/wk</b>                         | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>CP</b>                             | 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Workload in Hours</b>              | Independent Study Time 78, Study Time in Lecture 42                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Lecturer</b>                       | Prof. Arne Speerforck, Dr. Johannes Brunnemann                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Language</b>                       | DE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Cycle</b>                          | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Content</b>                        | <p>Lecture about equation-based, physical modelling using the modelling language Modelica and the free simulation tool OpenModelica 1.17.0.</p> <ul style="list-style-type: none"> <li>• Instruction and modelling of physical processes</li> <li>• Modelling and limits of model</li> <li>• Time constant, stiffness, stability, step size</li> <li>• Terms of object orientated programming</li> <li>• Differential equations of simple systems</li> <li>• Introduction into Modelica</li> <li>• Introduction into simulation tool</li> <li>• Example:Hydraulic systems and heat transfer</li> <li>• Example: System with different subsystems</li> </ul>                                                                                                                                                                                     |
| <b>Literature</b>                     | <p>[1] Modelica Association: "Modelica Language Specification - Version 3.5", Linköping, Sweden, 2021.</p> <p>[2] OpenModelica: OpenModelica 1.17.0, <a href="https://www.openmodelica.org">https://www.openmodelica.org</a> (siehe Download), 2021.</p> <p>[3] M. Tiller: "Modelica by Example", <a href="https://book.xogeny.com">https://book.xogeny.com</a>, 2014.</p> <p>[4] M. Otter, H. Elmqvist, et al.: "Objektorientierte Modellierung Physikalischer Systeme", at- Automatisierungstechnik (german), Teil 1 - 17, Oldenbourg Verlag, 1999 - 2000.</p> <p>[5] P. Fritzson: "Principles of Object-Oriented Modeling and Simulation with Modelica 3.3", Wiley-IEEE Press, New York, 2015.</p> <p>[6] P. Fritzson: "Introduction to Modeling and Simulation of Technical and Physical Systems with Modelica", Wiley, New York, 2011.</p> |

| Course L3151: System Simulation Modul |                                                     |
|---------------------------------------|-----------------------------------------------------|
| <b>Typ</b>                            | Recitation Section (large)                          |
| <b>Hrs/wk</b>                         | 2                                                   |
| <b>CP</b>                             | 2                                                   |
| <b>Workload in Hours</b>              | Independent Study Time 32, Study Time in Lecture 28 |
| <b>Lecturer</b>                       | Prof. Arne Speerforck, Dr. Johannes Brunnemann      |
| <b>Language</b>                       | DE                                                  |
| <b>Cycle</b>                          | WiSe                                                |
| <b>Content</b>                        | See interlocking course                             |
| <b>Literature</b>                     | See interlocking course                             |

| Module M1710: Smart Grid Technologies         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |  |        |    |
|-----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--------|----|
| Courses                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |  |        |    |
| Title                                         | Typ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |  | Hrs/wk | CP |
| Smart Grid Technologies (L2706)               | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |  | 3      | 4  |
| Smart Grid Technologies (L2707)               | Project-/problem-based Learning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |  | 2      | 2  |
| <b>Module Responsible</b>                     | Prof. Christian Becker                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |  |        |    |
| <b>Admission Requirements</b>                 | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |  |        |    |
| <b>Recommended Previous Knowledge</b>         | Fundamentals of Electrical Engineering,<br>Introduction to Control Systems,<br>Mathematics I, II, III<br>Electrical Power Systems I<br>Electrical Power Systems II                                                                                                                                                                                                                                                                                                                                                                                             |  |        |    |
| <b>Educational Objectives</b>                 | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |  |        |    |
| <b>Professional Competence</b>                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |  |        |    |
| <i>Knowledge</i>                              | Students are able to explain in detail and critically evaluate methods and technologies for operation of smart grids (i.e. intelligent distribution grids).                                                                                                                                                                                                                                                                                                                                                                                                    |  |        |    |
| <i>Skills</i>                                 | With completion of this module the students are able to analyze the impact of emerging technologies (such as renewables, energy storage and demand response) on the electric power system. They can formulate and apply computational intelligence techniques to power system operation problems. They can also explain what ICT technologies (such as digital twins and IoT) are relevant and suitable for distribution grid operation.                                                                                                                       |  |        |    |
| <b>Personal Competence</b>                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |  |        |    |
| <i>Social Competence</i>                      | The students can participate in specialized and interdisciplinary discussions, advance ideas and represent their own work results in front of others.                                                                                                                                                                                                                                                                                                                                                                                                          |  |        |    |
| <i>Autonomy</i>                               | Students can independently tap knowledge of the emphasis of the lectures and apply it within further research activities.                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |        |    |
| <b>Workload in Hours</b>                      | Independent Study Time 110, Study Time in Lecture 70                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |  |        |    |
| <b>Credit points</b>                          | 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |  |        |    |
| <b>Course achievement</b>                     | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |  |        |    |
| <b>Examination</b>                            | Presentation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |  |        |    |
| <b>Examination duration and scale</b>         | 30 min                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |  |        |    |
| <b>Assignment for the Following Curricula</b> | Electrical Engineering and Information Technology: Specialisation Control and Power Systems Engineering: Elective Compulsory<br>Energy Systems: Specialisation Energy Systems: Elective Compulsory<br>Energy Systems: Specialisation Green Energy Technologies: Elective Compulsory<br>International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory<br>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory |  |        |    |

| Course L2706: Smart Grid Technologies |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|---------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Typ</b>                            | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Hrs/wk</b>                         | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>CP</b>                             | 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Workload in Hours</b>              | Independent Study Time 78, Study Time in Lecture 42                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Lecturer</b>                       | Prof. Christian Becker, Dr. Payam Teimourzadeh Baboli                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Language</b>                       | DE/EN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Cycle</b>                          | WiSe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Content</b>                        | <p><b>Introduction to Smart Grids</b></p> <ul style="list-style-type: none"> <li>• Intelligent Distribution Grids</li> <li>• Paradigm shifts: Digitalization &amp; Sustainability</li> </ul> <p><b>Emerging technologies in distribution grids</b></p> <ul style="list-style-type: none"> <li>• Distributed Energy Resource (DER)</li> <li>• Battery Energy Storage (BES) technologies</li> <li>• Sector-coupling &amp; EV/V2G</li> <li>• Microgrids, Inverter-based Systems</li> <li>• Modelling and control of PV &amp; BESS</li> </ul> <p><b>Distribution grid management &amp; analysis</b></p> <ul style="list-style-type: none"> <li>• Distribution grid structure (Hamburg example)</li> <li>• Distribution grid management and operation architecture and functions <ul style="list-style-type: none"> <li>◦ Fault Detection, Isolation &amp; Restoration</li> <li>◦ Self-Healing in distribution systems</li> <li>◦ Volt-Var Optimization</li> <li>◦ Distribution Load Flow</li> </ul> </li> <li>• Demand Side Management &amp; Demand Response</li> <li>• Lab exercise (Smart Grid Operation)</li> </ul> <p><b>Computational intelligence and optimization techniques in Smart Grids</b></p> <ul style="list-style-type: none"> <li>• Computational challenges in Smart grid</li> <li>• Heuristic &amp; Analytic Optimization Methods</li> <li>• Intelligent Systems (Expert Systems, ML/AL)</li> <li>• Applications (optimal load flow, reactive capacitor placement)</li> <li>• Lab exercise (optimization formulation)</li> </ul> <p><b>ICT Technologies for Smart Grids</b></p> <ul style="list-style-type: none"> <li>• Advanced Metering Technologies: Smart Meters, RTU, PMU</li> <li>• Telecommunication Systems in Smart Grids (network basics and technologies)</li> <li>• Interoperability in Smart grids <ul style="list-style-type: none"> <li>◦ Smart Grid Architecture Model</li> <li>◦ Automation and Communication standards (IEC 61850, c37.118)</li> </ul> </li> <li>• Cyber security</li> <li>• Lab exercise (Grid automation protocols)</li> </ul> <p><b>Practical lesson-learned: Stromnetz Hamburg (SNH) perspective</b></p> <ul style="list-style-type: none"> <li>• Definition of Smart Grid and its requirements from industry view</li> <li>• Grid digitalization - examples of industrial projects</li> <li>• Flexible load management</li> <li>• Electromobility &amp; transportation sector integration</li> </ul> <p><b>Study visits:</b></p> <ul style="list-style-type: none"> <li>• Digital Substation in Harburg</li> <li>• Electric Bus charging station</li> </ul> <p>Stromnetz Hamburg Control Center</p> |
| <b>Literature</b>                     | <ul style="list-style-type: none"> <li>• Buchholz and Styczynski - 2020 - "Smart Grids: Fundamentals and Technologies in Electric Power Systems of the Future", Springer</li> <li>• Bernardon and Garcia - 2018 - "Smart Operation for Power Distribution Systems: Concepts and Applications", Springer</li> <li>• Momoh, 2012; "Smart Grid: Fundamentals of Design and Analysis", Wiley</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |



| Course L2707: Smart Grid Technologies |                                                       |
|---------------------------------------|-------------------------------------------------------|
| <b>Typ</b>                            | Project-/problem-based Learning                       |
| <b>Hrs/wk</b>                         | 2                                                     |
| <b>CP</b>                             | 2                                                     |
| <b>Workload in Hours</b>              | Independent Study Time 32, Study Time in Lecture 28   |
| <b>Lecturer</b>                       | Prof. Christian Becker, Dr. Payam Teimourzadeh Baboli |
| <b>Language</b>                       | DE/EN                                                 |
| <b>Cycle</b>                          | WiSe                                                  |
| <b>Content</b>                        | See interlocking course                               |
| <b>Literature</b>                     | See interlocking course                               |

| Module M2158: Data Science for Energy System Modelling |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |               |           |
|--------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|-----------|
| <b>Courses</b>                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |               |           |
| <b>Title</b>                                           | <b>Typ</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <b>Hrs/wk</b> | <b>CP</b> |
| Data Science for Energy System Modelling (L3460)       | Lecture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 4             | 6         |
| <b>Module Responsible</b>                              | Dozenten des SD V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |               |           |
| <b>Admission Requirements</b>                          | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |               |           |
| <b>Recommended Previous Knowledge</b>                  | Electrical Power Systems II: Operation and Information Systems of Electrical Power Grids / Dimensioning and Assessment of Renewable Energy Systems / Sustainable energy from wind and water / System simulation / Applied optimization in energy and process engineering                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |               |           |
| <b>Educational Objectives</b>                          | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |               |           |
| <b>Professional Competence</b>                         | <p><i>Knowledge</i> The module provides a general introduction to data-driven energy system modelling and covers the geographical and socio-economic potentials of renewable energy sources, their integration into existing energy systems, as well as the technical and economic analysis of storage and grid infrastructure. By working with real-world datasets, students learn how to collect, process, and interpret large amounts of data to support model-based decisions. In addition to essential mathematical optimization methods, the course offers hands-on experience with common open-source software tools and programming frameworks.</p> <p>The following topics are covered, among others:</p> <ul style="list-style-type: none"> <li>• Time series analysis of renewable energy sources (wind, solar) and energy demand</li> <li>• GIS-based assessment of renewable energy potentials</li> <li>• Modelling of energy storage and transmission networks</li> <li>• Fundamentals (and revision) of mathematical optimization</li> <li>• Electricity market design and system planning (e.g., merit order, market values, redispatch, nodal pricing)</li> <li>• Sector coupling and demand-side management</li> <li>• Uncertainty analysis and complexity-reduction methods</li> <li>• Implementation of energy system models in Python (e.g., pandas, geopandas, pyomo, cartopy, rasterio, PyPSA, atlite)</li> <li>• Visualization and communication of modelling results</li> </ul> <p><i>Skills</i> After successful participation in the module "Data Science for Energy System Modelling", students will be able to formulate different types of data-driven and energy-economic modelling and optimization problems. They can select and apply appropriate methods and tools (e.g., Python, Jupyter Notebooks, PyPSA, GAMS or comparable frameworks). Moreover, they are capable of independently developing strategies for model validation and for solving complex tasks, as well as interpreting and critically evaluating the obtained results.</p> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> Students are capable of:</p> <ul style="list-style-type: none"> <li>• developing solution strategies to complex energy system modelling problems in heterogeneous small groups,</li> <li>• giving and receiving constructive feedback in project teams and preparing joint results,</li> <li>• engaging in professional discussions and presenting results in a structured manner.</li> </ul> <p><i>Autonomy</i> Students are capable of:</p> <ul style="list-style-type: none"> <li>• independently acquiring new knowledge through relevant literature and open-source documentation,</li> <li>• identifying open questions and addressing them using suitable methods,</li> <li>• reflecting on results and solution approaches to make them applicable to future tasks.</li> </ul> |               |           |
| <b>Workload in Hours</b>                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |               |           |
| <b>Credit points</b>                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |               |           |
| <b>Course achievement</b>                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |               |           |
| <b>Examination</b>                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |               |           |
| <b>Examination duration and scale</b>                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |               |           |
| <b>Assignment for the Following Curricula</b>          | Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |               |           |

| Course L3460: Data Science for Energy System Modelling |                                                      |
|--------------------------------------------------------|------------------------------------------------------|
| <b>Typ</b>                                             | Lecture                                              |
| <b>Hrs/wk</b>                                          | 4                                                    |
| <b>CP</b>                                              | 6                                                    |
| <b>Workload in Hours</b>                               | Independent Study Time 124, Study Time in Lecture 56 |
| <b>Lecturer</b>                                        | NN                                                   |
| <b>Language</b>                                        | EN                                                   |
| <b>Cycle</b>                                           | WiSe                                                 |
| <b>Content</b>                                         |                                                      |
| <b>Literature</b>                                      |                                                      |

## Thesis

### Module M-002: Master Thesis

#### Courses

| Title                                                                       | Typ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Hrs/wk | CP |
|-----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|----|
| <b>Module Responsible</b>                                                   | Professoren der TUHH                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |        |    |
| <b>Admission Requirements</b>                                               | <ul style="list-style-type: none"> <li>According to General Regulations §21 (1):</li> </ul> <p>At least 60 credit points have to be achieved in study programme. The examinations board decides on exceptions.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |    |
| <b>Recommended Previous Knowledge</b>                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |        |    |
| <b>Educational Objectives</b>                                               | After taking part successfully, students have reached the following learning results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |        |    |
| <b>Professional Competence</b><br><i>Knowledge</i>                          | <ul style="list-style-type: none"> <li>The students can use specialized knowledge (facts, theories, and methods) of their subject competently on specialized issues.</li> <li>The students can explain in depth the relevant approaches and terminologies in one or more areas of their subject, describing current developments and taking up a critical position on them.</li> <li>The students can place a research task in their subject area in its context and describe and critically assess the state of research.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |        |    |
| <i>Skills</i><br><br><b>Personal Competence</b><br><i>Social Competence</i> | <p>The students are able:</p> <ul style="list-style-type: none"> <li>To select, apply and, if necessary, develop further methods that are suitable for solving the specialized problem in question.</li> <li>To apply knowledge they have acquired and methods they have learnt in the course of their studies to complex and/or incompletely defined problems in a solution-oriented way.</li> <li>To develop new scientific findings in their subject area and subject them to a critical assessment.</li> </ul> <p>Students can</p> <ul style="list-style-type: none"> <li>Both in writing and orally outline a scientific issue for an expert audience accurately, understandably and in a structured way.</li> <li>Deal with issues competently in an expert discussion and answer them in a manner that is appropriate to the addressees while upholding their own assessments and viewpoints convincingly.</li> </ul>                                                                                                                         |        |    |
| <i>Autonomy</i>                                                             | <p>Students are able:</p> <ul style="list-style-type: none"> <li>To structure a project of their own in work packages and to work them off accordingly.</li> <li>To work their way in depth into a largely unknown subject and to access the information required for them to do so.</li> <li>To apply the techniques of scientific work comprehensively in research of their own.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |        |    |
| <b>Workload in Hours</b>                                                    | Independent Study Time 900, Study Time in Lecture 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |        |    |
| <b>Credit points</b>                                                        | 30                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |        |    |
| <b>Course achievement</b>                                                   | None                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |        |    |
| <b>Examination</b>                                                          | Thesis                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |        |    |
| <b>Examination duration and scale</b>                                       | According to General Regulations                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |        |    |
| <b>Assignment for the Following Curricula</b>                               | Civil Engineering: Thesis: Compulsory<br>Bioprocess Engineering: Thesis: Compulsory<br>Chemical and Bioprocess Engineering: Thesis: Compulsory<br>Chemical and Bioprocess Engineering: Thesis: Compulsory<br>Computational Methods and Machine Learning in Engineering: Thesis: Compulsory<br>Computer Science: Thesis: Compulsory<br>Data Science: Thesis: Compulsory<br>Electrical Engineering and Information Technology: Thesis: Compulsory<br>Energy Systems: Thesis: Compulsory<br>Environmental Engineering: Thesis: Compulsory<br>Aircraft Systems Engineering: Thesis: Compulsory<br>Global Innovation Management: Thesis: Compulsory<br>Computer Science in Engineering: Thesis: Compulsory<br>Information and Communication Systems: Thesis: Compulsory<br>Interdisciplinary Mathematics: Thesis: Compulsory<br>International Production Management: Thesis: Compulsory<br>International Management and Engineering: Thesis: Compulsory<br>Joint European Master in Environmental Studies - Cities and Sustainability: Thesis: Compulsory |        |    |

|                                                                                 |
|---------------------------------------------------------------------------------|
| Logistics, Infrastructure and Mobility: Thesis: Compulsory                      |
| Aeronautics: Thesis: Compulsory                                                 |
| Mechanical Engineering - Product Development and Production: Thesis: Compulsory |
| Materials Science and Engineering: Thesis: Compulsory                           |
| Mechanical Engineering and Management: Thesis: Compulsory                       |
| Mechatronics: Thesis: Compulsory                                                |
| Biomedical Engineering: Thesis: Compulsory                                      |
| Microelectronics and Microsystems: Thesis: Compulsory                           |
| Naval Architecture and Ocean Engineering: Thesis: Compulsory                    |
| Product Development, Materials and Production: Thesis: Compulsory               |
| Renewable Energies: Thesis: Compulsory                                          |
| Naval Architecture and Ocean Engineering: Thesis: Compulsory                    |
| Ship and Offshore Technology: Thesis: Compulsory                                |
| Theoretical Mechanical Engineering: Thesis: Compulsory                          |
| Process Engineering: Thesis: Compulsory                                         |
| Water and Environmental Engineering: Thesis: Compulsory                         |
| Certification in Engineering & Advisory in Aviation: Thesis: Compulsory         |