



Module Manual

Master of Science (M.Sc.)

Renewable Energies Dual study program

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Program description

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.

In addition to the foundational curriculum taught at TUHH, seminars on developing personal skills are integrated into the dual study programme, in the context of transfer between theory and practice. These seminars correspond to the modern professional requirements expected of an engineer, as well as promoting the link between the two places of learning.

The intensive dual courses at TUHH integrating practical experience consist of an academic-oriented and a practice-oriented element, which are completed at two places of learning. The academic-oriented element comprises study at TUHH. The practice-oriented element is coordinated with the study programme in terms of content and time, and consists of practical modules and phases spent in an affiliate company during periods when there are no lectures.

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.

In addition, students acquire basic professional and personal skills as part of the dual study programme that enable them to enter professional practice at an early stage and to go on to further study. Students also gain practical work experience through the integrated practical modules. Graduates of the dual course have broad foundational knowledge, fundamental skills for academic work and relevant personal competences.

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.

By continually switching places of learnings throughout the dual study programme, it is possible for theory and practice to be interlinked. Students reflect theoretically on their individual professional practical experience, and apply the results of their reflection to new forms of practice. They also test theoretical elements of the course in a practical setting, and use their findings as a stimulus for theoretical debate.

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% describes 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.

The structural model of the dual study programme follows a module-differentiating approach. Given the practice-oriented element, the curriculum of the dual study programme is different compared to a standard Bachelor's course. Five practical modules are completed at the dual students' partner company as part of corresponding practical terms during lecture-free periods.

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

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

Course L0062: Biofuels Process Technology	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Oliver Lüdtke
Language	DE
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Life Cycle Assessment <ul style="list-style-type: none"> ◦ Good example for the evaluation of CO₂ savings potential by alternative fuels - Choice of system boundaries and databases • Bioethanol production <ul style="list-style-type: none"> ◦ 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 ... • Biodiesel production <ul style="list-style-type: none"> ◦ Procedural options for solid / liquid separation, including basic equations for estimating power, energy demand, selectivity and throughput • Biomethane production <ul style="list-style-type: none"> ◦ Chemical reactions that are relevant in the production of biofuels, including equilibria, activation energies, shift reactions
Literature	Skriptum zur Vorlesung

Course L1769: World Market for Commodities from Agriculture and Forestry	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Michael Köhl, Bernhard Chilla
Language	DE
Cycle	WiSe
Content	<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 & 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 & 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 & 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>
Literature	Lecture material

Course L1767: Thermal Biomass Utilization	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Martin Kaltschmitt
Language	DE
Cycle	WiSe
Content	<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"> • Biomass as an energy carrier within the energy system; use of biomass in Germany and world-wide, overview on the content of the course • Photosynthesis, composition of organic matter, plant production, energy crops, residues, organic waste • Biomass provision chains for woody and herbaceous biomass, harvesting and provision, transport, storage, drying • Thermo-chemical conversion of solid biofuels <ul style="list-style-type: none"> ◦ Basics of thermo-chemical conversion ◦ 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 ◦ Gasification: Gasification technologies, producer gas cleaning technologies, options to use the cleaned producer gas for the provision of heat, electricity and/or fuels ◦ 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 • 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) • Bio-chemical conversion of biomass <ul style="list-style-type: none"> ◦ Basics of bio-chemical conversion ◦ 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 ◦ Ethanol production: Process technologies for feedstock containing sugar, starch or celluloses, use of ethanol as a fuel, use of the stillage
Literature	Kaltschmitt, M.; Hartmann, H. (Hrsg.): Energie aus Biomasse; Springer, Berlin, Heidelberg, 2009, 2. Auflage

Course L2386: Thermal Biomass Utilization	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Martin Kaltschmitt, Dr. Marvin Scherzinger
Language	DE
Cycle	WiSe
Content	<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>
Literature	<p>- Kaltschmitt, Martin; Hartmann, Hans; Hofbauer, Hermann: Energie aus Biomasse: Grundlagen, Techniken und Verfahren. 3. Auflage. Berlin Heidelberg: Springer Science & 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
Module Responsible	Prof. Martin Kaltschmitt			
Admission Requirements	None			
Recommended Previous Knowledge	Environmental Assessment			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	<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>			
Personal Competence				
<i>Social Competence</i>				
<i>Autonomy</i>				
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	150 minutes written exam + Written essay from project seminar			
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Renewable Energies: Core Qualification: Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory			

Course L0007: Aspects of Sustainability Management	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Charlotte Weinspach
Language	DE
Cycle	WiSe
Content	<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"> • What is "sustainability"? • Why is this concept an important topic for companies? • What opportunities and business risks are addressed or are associated with it? • 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? • What concepts or frameworks exist for the implementation of sustainability management in companies? • Which sustainability labels exist for products or companies? What do they have in common, and where do they differ? <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>
Literature	<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	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Martin Kaltschmitt
Language	DE
Cycle	WiSe
Content	<ul style="list-style-type: none"> • 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 • 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 • 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? • Feasibility study, requirements and content of a feasibility study • 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. • Company structures; which company structure is the most appropriate for the various applications? What are the pros and cons? • Risk management: how the risks of renewable energy projects can be best determined? How the minimizing of risk can be ensured? • 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? • Acceptance: how the acceptance of an application for the use of renewable energy can be assessed and improved? How the acceptance can be measured? • Organization of realization of a project: how the construction phase of a renewable energy system is organized after the end of the planning period? • Acceptance: Which are the acceptance steps until the regular continuous operation (VOB acceptance, safety acceptance, approval by authority) • Examples: good and less good examples of project development
Literature	<ul style="list-style-type: none"> • Script zur Vorlesung mit Literaturhinweisen

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

Course L0005: Economic Aspects of Energy Projects	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Andreas Wiese
Language	DE
Cycle	WiSe
Content	<ul style="list-style-type: none"> • 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 • Cost estimates and cost calculations <ul style="list-style-type: none"> ◦ Definitions ◦ Cost calculation ◦ Cost estimation ◦ Calculation of costs for the provision of work and power ◦ Cost summaries for renewable energy technologies ◦ Energy Storage: cost overviews; impact on the cost of renewable energy projects • Efficiency calculation <ul style="list-style-type: none"> ◦ Definitions ◦ Methods: static methods, dynamic methods (eg. LCOE (levelised cost of electricity)) ◦ Economic versus national economic approach ◦ Power and work in cost accounting ◦ Energy storage and its influence on the efficiency calculation • The due diligence process as an attendant of economic analysis • Consideration of uncertainty in projects for renewable energy <ul style="list-style-type: none"> ◦ Definitions ◦ Technical uncertainty ◦ Cost uncertainties ◦ Other uncertainties • Project financing <ul style="list-style-type: none"> ◦ Definitions ◦ Project -versus corporate finance ◦ Funding models ◦ Equity ratio , DSCR ◦ Treatment of risks in project financing ◦ Funding opportunities for renewable energy projects ◦ Possible funding approaches ◦ Legal requirements in Germany (EEG) ◦ Emissions trading and carbon credits
Literature	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		
Professional Competence	<p>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.</p> <p>Students are able to solve scientific problems in the context of heat and electricity supply using renewable energy systems by:</p> <ul style="list-style-type: none">• using module-comprehensive knowledge for different applications,• evaluating alternative input parameter regarding the solution of the task in the case of incomplete information (technical, economical and ecological parameter),• a systematic documentation of the work results in form of a written version, the presentation itself and the defense of contents.		
Knowledge			
Skills			
Personal Competence			
Social Competence	<p>Students can</p> <ul style="list-style-type: none">• respectfully work together as a team with around 2-3 members,• participate in subject-specific and interdisciplinary discussions in the area of dimensioning and analysis of potentials of heat and electricty supply using renewable energie, and can develop cooperated solutions,• defend their own work results in front of fellow students and• assess the performance of fellow students in comparison to their own performance. Furthermore, they can accept professional constructive criticism.		
Autonomy	<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>		
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 Renewable Energies: Core Qualification: Compulsory		
Course L0137: Environmental Technology and Energy Economics			
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">• Preliminary discussion with the rules of the lecture• 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)• "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• Submission of a written solution of the task and distribution to the participants by the student / group of students• Presentation of the edited theme (20 min) with PPT presentation and subsequent discussion (20 minutes)• Attendance is mandatory for all seminars		
Literature	Eigenständiges Literaturstudium in der Bibliothek und aus anderen Quellen.		

Course L0046: Electricity Generation from Renewable Sources of Energy	
Typ	Seminar
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"> • Preliminary discussion with the seminar rules • Distribution of the topics related to the subject of the seminar to individual students / groups of students (depending on the number of participating students) • Delivery of a five-page summary of the seminar topic and distribution to the participants by the student / group of students • Presentation of the processed topic (30 min) with PPT presentation and subsequent discussion (20 minutes) • Attendance is mandatory for all seminars
Literature	<ul style="list-style-type: none"> • Eigenständiges Literaturstudium in der Bibliothek und aus anderen Quellen.

Course L0045: Heat Provision from Renewable Sources of Energy	
Typ	Seminar
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	SoSe
Content	<ul style="list-style-type: none"> • Preliminary discussion with the seminar rules • Distribution of the topics related to the subject of the seminar to individual students / groups of students (depending on the number of participating students) • Delivery of a five-page summary of the seminar topic and distribution to the participants by the student / group of students • Presentation of the processed topic (30 min) with PPT presentation and subsequent discussion (20 minutes) • Attendance is mandatory for all seminars
Literature	Eigenständiges Literaturstudium in der Bibliothek und aus anderen Quellen.

Module M1759: Linking theory and practice (dual study program, Master's degree)	
Module Responsible	Dr. Henning Haschke
Admission Requirements	None
Recommended Previous Knowledge	<ul style="list-style-type: none"> • Successful completion of practical modules as part of the dual Bachelor's course • Module "interlinking theory and practice as part of the dual Master's course"
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence <i>Knowledge</i>	Dual students can describe and classify selected classic and current theories, concepts and methods <ul style="list-style-type: none"> • related to project management and • change and transformation management ... and apply them to specific situations, processes and plans in a personal, professional context.
Personal Competence <i>Social Competence</i>	Dual students ... <ul style="list-style-type: none"> • ... can responsibly lead interdisciplinary teams within the framework of complex tasks and problems. • ... engage in sector-specific and cross-sectoral discussions with experts, stakeholders and staff, representing their approaches, points of view and work results.
Personal Competence <i>Autonomy</i>	Dual students ... <ul style="list-style-type: none"> • ... define, reflect and evaluate goals and measures for complex application-oriented projects and change processes. • ... shape their professional area of responsibility independently and sustainably. • ... take responsibility for their actions and for the results of their work.
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	Studienbegleitende und semesterübergreifende Dokumentation: Die Leistungspunkte für das Modul werden durch die Anfertigung eines digitalen Lern- und Entwicklungsberichtes (E-Portfolio) erworben. Dabei handelt es sich um eine fortlaufende Dokumentation und Reflexion der Lernerfahrungen und der Kompetenzentwicklung im Bereich der Personalen Kompetenz.

Course L2890: Responsible Project Management in Engineering (for Dual Study Program)	
Typ	Seminar
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Dr. Henning Haschke, Heiko Sieben
Language	DE
Cycle	WiSe/SoSe
Content	<ul style="list-style-type: none"> • Theories and methods of project management • Innovation management • Agile project management • Fundamentals of classic and agile methods • Hybrid use of classic and agile methods • Roles, perspectives and stakeholders throughout the project • Initiating and coordinating complex engineering projects • Principles of moderation, team management, team leadership, conflict management • Communication structures: in-house, cross-company • Public information policy • Promoting commitment and empowerment • Sharing experience with specialists and managers from the engineering sector • Documenting and reflecting on learning experiences
Literature	Seminarapparat

Course L2891: Responsible Change and Transformation Management in Engineering (for Dual Study Program)	
Typ	Seminar
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Dr. Henning Haschke, Heiko Sieben
Language	DE
Cycle	WiSe/SoSe
Content	<ul style="list-style-type: none"> • Basic concepts, opportunities and limits of organisational change • Models and methods of organisational design and development • Strategic orientation and change, and their short-, medium- and long-term consequences for individuals, organisations and society as a whole • Roles, perspectives and stakeholders in change processes • Initiating and coordinating change measures in engineering • Phase models of organisational change (Lewin, Kotter, etc.) • Change-oriented information policy and dealing with resistance and uncertainty • Promoting commitment and empowerment • Successfully handling change and transformation: personally, as an employee, as a manager (personal, professional, organisational) • Company-level and globally (systemic) • Sharing experience with specialists and managers from the engineering sector • Documenting and reflecting on learning experiences
Literature	Seminarapparat

Module M1756: Practical module 1 (dual study program, Master's degree)			
Courses			
Title	Typ	Hrs/wk	CP
Practical term 1 (dual study program, Master's degree) (L2887)		0	10
Module Responsible	Dr. Henning Haschke		
Admission Requirements	None		
Recommended Previous Knowledge	<ul style="list-style-type: none"> Successful completion of a compatible dual B.Sc. at TU Hamburg or comparable practical work experience and competences in the area of interlinking theory and practice Course D from the module on interlinking theory and practice as part of the dual Master's course 		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence <i>Knowledge</i> <i>Skills</i> Personal Competence <i>Social Competence</i> <i>Autonomy</i>	<p>Dual students ...</p> <ul style="list-style-type: none"> ... combine their knowledge of facts, principles, theories and methods gained from previous study content with acquired practical knowledge - in particular their knowledge of practical professional procedures and approaches, in the current field of activity in engineering. ... have a critical understanding of the practical applications of their engineering subject. <p>Dual students ...</p> <ul style="list-style-type: none"> ... apply technical theoretical knowledge to complex, interdisciplinary problems within the company, and evaluate the associated work processes and results, taking into account different possible courses of action. ... implement the university's application recommendations with regard to their current tasks. ... develop solutions as well as procedures and approaches in their field of activity and area of responsibility. <p>Dual students ...</p> <ul style="list-style-type: none"> ... work responsibly in project teams within their working area and proactively deal with problems within their team. ... represent complex engineering viewpoints, facts, problems and solution approaches in discussions with internal and external stakeholders. <p>Dual students ...</p> <ul style="list-style-type: none"> ... define goals for their own learning and working processes as engineers. ... reflect on learning and work processes in their area of responsibility. ... reflect on the relevance of subject modules specialisations and specialisation for work as an engineer, and also implement the university's application recommendations and the associated challenges to positively transfer knowledge between theory and practice. 		
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0		
Credit points	10		
Course achievement	None		
Examination	Written elaboration		
Examination duration and scale	Documentation accompanying studies and across semesters: Module credit points are earned by completing a digital learning and development report (e-portfolio). This documents and reflects individual learning experiences and skills development relating to interlinking theory and practice, as well as professional practice. In addition, the partner company provides proof to the dual@TUHH Coordination Office that the dual student has completed the practical phase.		
Assignment for the Following Curricula	Civil Engineering: Core Qualification: Compulsory Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Electrical Engineering and Information Technology: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Compulsory Energy Systems: Core Qualification: Compulsory Environmental Engineering: Core Qualification: Compulsory Aircraft Systems Engineering: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Information and Communication Systems: Core Qualification: Compulsory International Management and Engineering: Core Qualification: Compulsory Logistics, Infrastructure and Mobility: Core Qualification: Compulsory Aeronautics: Core Qualification: Compulsory Mechanical Engineering - Product Development and Production: Core Qualification: Compulsory Materials Science and Engineering: Core Qualification: Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Biomedical Engineering: Core Qualification: Compulsory Microelectronics and Microsystems: Core Qualification: Compulsory		

	Product Development, Materials and Production: Core Qualification: Compulsory Renewable Energies: Core Qualification: Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory Process Engineering: Core Qualification: Compulsory Water and Environmental Engineering: Core Qualification: Compulsory
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Course L2887: Practical term 1 (dual study program, Master's degree)	
Typ	
Hrs/wk	0
CP	10
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0
Lecturer	Dr. Henning Haschke
Language	DE
Cycle	WiSe/SoSe
Content	<p>Company onboarding process</p> <ul style="list-style-type: none"> Assigning a professional field of activity as an engineer (B.Sc.) and associated fields of work Establishing responsibilities and authorisation of the dual student within the company as an engineer (B.Sc.) Working independently in a team and on selected projects - across departments and, if applicable, across companies Scheduling the current practical module with a clear correlation to work structures Scheduling the examination phase/subsequent study semester <p>Operational knowledge and skills</p> <ul style="list-style-type: none"> Company-specific: Responsibility as an engineer (B.Sc.) in their own area of work, coordinating team and project work, dealing with complex contexts and unsolved problems, developing and implementing innovative solutions Subject specialisation (corresponding to the chosen course [M.Sc.]) in the field of activity Systemic skills Implementing the university's application recommendations (theory-practice transfer) in corresponding work and task areas across the company <p>Sharing/reflecting on learning</p> <ul style="list-style-type: none"> Creating an e-portfolio Importance of course contents (M.Sc.) when working as an engineer Importance of development and innovation when working as an engineer
Literature	<ul style="list-style-type: none"> Studierendenhandbuch Betriebliche Dokumente Hochschulseitige Handlungsempfehlungen zum Theorie-Praxis-Transfer

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
Module Responsible	Prof. Christian Becker			
Admission Requirements	None			
Recommended Previous Knowledge	Fundamentals of Electrical Engineering, Electrical Power Systems I, Mathematics I, II, III			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence <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.			
Personal Competence <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.			
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70			
Credit points	6			
Course achievement	None			
Examination	Oral exam			
Examination duration and scale	45 min			
Assignment for the Following Curricula	Electrical Engineering and Information Technology: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Compulsory Energy Systems: Specialisation Energy Systems: Elective Compulsory Computer Science in Engineering: Specialisation II. Engineering Science: Elective Compulsory Renewable Energies: Core Qualification: Compulsory			

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

Course L1697: Electrical Power Systems II: Operation and Information Systems of Electrical Power Grids	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Christian Becker
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	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
Module Responsible	Prof. Michael Schlüter			
Admission Requirements	None			
Recommended Previous Knowledge	Technische Thermodynamik I-II Wärme- und Stoffübertragung			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence				
<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.			
Personal Competence				
<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.			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	Compulsory	Bonus	Form	Description
	No	10 %	Group discussion	
Examination	Subject theoretical and practical work			
Examination duration and scale	Poster discussion			
Assignment for the Following Curricula	Energy Systems: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory Renewable Energies: Core Qualification: Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory			

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

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

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			
Professional Competence <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>	Students can apply the acquired theoretical foundations of exemplary energy systems using solar radiation. In this context, for example they can assess and evaluate potential and constraints of solar energy systems with respect to different geographical assumptions. They are able to dimension solar energy systems in consideration of technical aspects and given assumptions. Using module-comprehensive knowledge students can evaluate the economic and ecologic conditions of these systems. They can select calculation methods within the radiation theory for these topics.			
Personal Competence <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 International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory Renewable Energies: Core Qualification: Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory			

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

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

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

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

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
Module Responsible	Prof. Martin Kaltschmitt		
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		
Professional Competence <i>Knowledge</i> <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"> • development of modul-comprehensive approaches for the dimensioning and design of production processes • evaluating alternatives input parameter to solve the particular task even with incomplete information, • a systematic documentation of the work results in form of a written version, the presentation itself and the defense of contents. <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>		
Personal Competence <i>Social Competence</i> <i>Autonomy</i>	<p>Students can</p> <ul style="list-style-type: none"> • respectfully work together as a team with around 2-3 members, • participate in subject-specific and interdisciplinary discussions in the area of dimensioning and design of production processes, and can develop cooperated solutions, • defend their own work results in front of fellow students and <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>		
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	Written report incl. presentation		
Assignment for the Following Curricula	<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	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Oliver Lüdtkke
Language	DE
Cycle	SoSe
Content	<p>I. Repetition of engineering basics</p> <ol style="list-style-type: none"> 1. Shell and tube heat exchangers 2. Steam generators and refrigerating machines 3. Pumps and turbines 4. Flow in piping networks 5. Pumping and mixing of non-newtonian fluids 6. Requirements to a detailed layout plan <p>II. Calculation:</p> <ol style="list-style-type: none"> 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"> ◦ Mass and energy balances (Aspen) ◦ Equipment design (heat exchangers, pumps, pipes, tanks, etc.) (◦ Isolation, wall thickness and material selection ◦ Energy demand (electrical, heat or cooling), design of steam boilers and appliances ◦ Selection of fittings, measuring instruments and safety equipment ◦ Definition of main control loops 2. Hereby, the dependencies of transport phenomena between certain plant sections become evident and methods of calculation are introduced. 3. In Detail Engineering , it is focused on aspects of plant engineering planning that are relevant for the subsequent construction of the plant. 4. Depending of time requirement and group size a cost estimation and preparation of a complete R&I flow chart can be implemented as well.
Literature	<p>Perry, R.;Green, R.: Perry's Chemical Engineers' Handbook, 8th Edition, McGraw Hill Professional, 2007</p> <p>Sinnot, R. K.: Chemical Engineering Design, Elsevier, 2014</p>

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

Module M1757: Practical module 2 (dual study program, Master's degree)			
Courses			
Title	Typ	Hrs/wk	CP
Practical term 2 (dual study program, Master's degree) (L2888)		0	10
Module Responsible	Dr. Henning Haschke		
Admission Requirements	None		
Recommended Previous Knowledge	<ul style="list-style-type: none"> Successful completion of practical module 1 as part of the dual Master's course course D from the module on interlinking theory and practice as part of the dual Master's course 		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence <i>Knowledge</i>	Dual students ... <ul style="list-style-type: none"> ... combine their knowledge of facts, principles, theories and methods gained from previous study content with acquired practical knowledge - in particular their knowledge of practical professional procedures and approaches, in the current field of activity in engineering. ... have a critical understanding of the practical applications of their engineering subject. 		
<i>Skills</i>	Dual students ... <ul style="list-style-type: none"> ... apply technical theoretical knowledge to complex, interdisciplinary problems within the company, and evaluate the associated work processes and results, taking into account different possible courses of action. ... implement the university's application recommendations with regard to their current tasks. ... develop (new) solutions as well as procedures and approaches in their field of activity and area of responsibility - including in the case of frequently changing requirements (systemic skills). 		
Personal Competence <i>Social Competence</i>	Dual students ... <ul style="list-style-type: none"> ... work responsibly in cross-departmental and interdisciplinary project teams and proactively deal with problems within their team. ... represent complex engineering viewpoints, facts, problems and solution approaches in discussions with internal and external stakeholders and develop these further together. 		
<i>Autonomy</i>	Dual students ... <ul style="list-style-type: none"> ... define goals for their own learning and working processes as engineers. ... reflect on learning and work processes in their area of responsibility. ... reflect on the relevance of subject modules specialisations and specialisation for work as an engineer, and also implement the university's application recommendations and the associated challenges to positively transfer knowledge between theory and practice. 		
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0		
Credit points	10		
Course achievement	None		
Examination	Written elaboration		
Examination duration and scale	Documentation accompanying studies and across semesters: Module credit points are earned by completing a digital learning and development report (e-portfolio). This documents and reflects individual learning experiences and skills development relating to interlinking theory and practice, as well as professional practice. In addition, the partner company provides proof to the dual@TUHH Coordination Office that the dual student has completed the practical phase.		
Assignment for the Following Curricula	Civil Engineering: Core Qualification: Compulsory Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Electrical Engineering and Information Technology: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Compulsory Energy Systems: Core Qualification: Compulsory Environmental Engineering: Core Qualification: Compulsory Aircraft Systems Engineering: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Information and Communication Systems: Core Qualification: Compulsory International Management and Engineering: Core Qualification: Compulsory Logistics, Infrastructure and Mobility: Core Qualification: Compulsory Aeronautics: Core Qualification: Compulsory Mechanical Engineering - Product Development and Production: Core Qualification: Compulsory Materials Science and Engineering: Core Qualification: Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Biomedical Engineering: Core Qualification: Compulsory		

	Microelectronics and Microsystems: Core Qualification: Compulsory Product Development, Materials and Production: Core Qualification: Compulsory Renewable Energies: Core Qualification: Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory Process Engineering: Core Qualification: Compulsory Water and Environmental Engineering: Core Qualification: Compulsory
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Course L2888: Practical term 2 (dual study program, Master's degree)	
Typ	
Hrs/wk	0
CP	10
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0
Lecturer	Dr. Henning Haschke
Language	DE
Cycle	WiSe/SoSe
Content	<p>Company onboarding process</p> <ul style="list-style-type: none"> Assigning a professional field of activity as an engineer (B.Sc.) and associated fields of work Establishing responsibilities and authorisation of the dual student within the company as an engineer (B.Sc.) Taking personal responsibility within a team and on selected projects - across departments and, if applicable, across companies Scheduling the current practical module with a clear correlation to work structures Scheduling the examination phase/subsequent study semester <p>Operational knowledge and skills</p> <ul style="list-style-type: none"> Company-specific: Responsibility as an engineer (B.Sc.) in their own area of work, coordinating team and project work, dealing with complex contexts and unsolved problems, developing and implementing innovative solutions Subject specialisation (corresponding to the chosen course [M.Sc.]) in the field of activity Systemic skills Implementing the university's application recommendations (theory-practice transfer) in corresponding work and task areas across the company <p>Sharing/reflecting on learning</p> <ul style="list-style-type: none"> Updating their e-portfolio Importance of course contents (M.Sc.) when working as an engineer Importance of development and innovation when working as an engineer
Literature	<ul style="list-style-type: none"> Studierendenhandbuch Betriebliche Dokumente Hochschulseitige Anwendungsempfehlungen zum Theorie-Praxis-Transfer

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
Module Responsible	Dr. Marvin Scherzinger		
Admission Requirements	None		
Recommended Previous Knowledge	Module: Technical Thermodynamics I, Module: Technical Thermodynamics II, Module: Fundamentals of Fluid Mechanics		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence <i>Knowledge</i> <i>Skills</i> Personal Competence <i>Social Competence</i> <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>		
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	180 min		
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory Mechanical Engineering - Product Development and Production: Specialisation Product Development: Elective Compulsory Mechanical Engineering - Product Development and Production: Specialisation Production: Elective Compulsory Mechanical Engineering - Product Development and Production: Specialisation Materials: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Renewable Energies: Core Qualification: Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Cities: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory		

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

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

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

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

Module M2157: Technologies for electric and hydrogen mobility				
Courses				
Title		Type	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. 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 International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Renewable Energies: Core Qualification: Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory			

Course L1831: Applied Fuel Cell Technology	
Type	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Klaus Bonhoff
Language	DE
Cycle	SoSe
Content	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.
Literature	Vorlesungsunterlagen

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

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

Module M0742: Thermal Energy Systems				
Courses				
Title	Typ		Hrs/wk	CP
Thermal Energy Systems (L0023)	Lecture		3	5
Thermal Energy Systems (L0024)	Recitation Section (large)		1	1
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 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.</p> <p><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.</p> <p><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.</p> <p><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.</p>			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	60 min			
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Energy Systems: Specialisation Energy Systems: Compulsory Energy Systems: Specialisation Marine Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory Mechanical Engineering - Product Development and Production: Core Qualification: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Renewable Energies: Core Qualification: Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory			

Course L0023: Thermal Energy Systems	
Typ	Lecture
Hrs/wk	3
CP	5
Workload in Hours	Independent Study Time 108, Study Time in Lecture 42
Lecturer	Prof. Gerhard Schmitz, Prof. Arne Speerforck
Language	DE
Cycle	WiSe
Content	<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>
Literature	<ul style="list-style-type: none"> • Schmitz, G.: Klimaanlagen, Skript zur Vorlesung • VDI Wärmeatlas, 11. Auflage, Springer Verlag, Düsseldorf 2013 • Herwig, H.; Moschallski, A.: Wärmeübertragung, Vieweg+Teubner Verlag, Wiesbaden 2009 • Recknagel, H.; Sprenger, E.; Schrammek, E.-R.: Taschenbuch für Heizung- und Klimatechnik 2013/2014, 76. Auflage, Deutscher Industrieverlag, 2013

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

Module M1758: Practical module 3 (dual study program, Master's degree)			
Courses			
Title	Typ	Hrs/wk	CP
Practical term 3 (dual study program, Master's degree) (L2889)		0	10
Module Responsible	Dr. Henning Haschke		
Admission Requirements	None		
Recommended Previous Knowledge	<ul style="list-style-type: none"> Successful completion of practical module 2 as part of the dual Master's course course E from the module on interlinking theory and practice as part of the dual Master's course 		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence <i>Knowledge</i>	Dual students ... <ul style="list-style-type: none"> ... combine their comprehensive and specialised engineering knowledge acquired from previous study contents with the strategy-oriented practical knowledge gained from their current field of work and area of responsibility. ... have a critical understanding of the practical applications of their engineering subject, as well as related fields when implementing innovations. 		
<i>Skills</i>	Dual students ... <ul style="list-style-type: none"> ... apply specialised and conceptual skills to solve complex, sometimes interdisciplinary problems within the company, and evaluate the associated work processes and results, taking into account different possible courses of action. ... implement the university's application recommendations with regard to their current tasks. ... develop new solutions as well as procedures and approaches to implement operational projects and assignments - even when facing frequently changing requirements and unpredictable changes (systemic skills). ... can use academic methods to develop new ideas and procedures for operational problems and issues, and to assess these with regard to their usability. 		
Personal Competence <i>Social Competence</i>	Dual students ... <ul style="list-style-type: none"> ... work responsibly in cross-departmental and interdisciplinary project teams and proactively deal with problems within their team. ... can promote the professional development of others in a targeted manner. ... represent complex and interdisciplinary engineering viewpoints, facts, problems and solution approaches in discussions with internal and external stakeholders and develop these further together. 		
<i>Autonomy</i>	Dual students ... <ul style="list-style-type: none"> ... reflect on learning and work processes in their area of responsibility. ... define goals for new application-oriented tasks, projects and innovation plans while reflecting on potential effects on the company and the public. ... reflect on the relevance of areas of specialisation and research for work as an engineer, and also implement the university's application recommendations and the associated challenges to positively transfer knowledge between theory and practice. 		
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0		
Credit points	10		
Course achievement	None		
Examination	Written elaboration		
Examination duration and scale	Documentation accompanying studies and across semesters: Module credit points are earned by completing a digital learning and development report (e-portfolio). This documents and reflects individual learning experiences and skills development relating to interlinking theory and practice, as well as professional practice. In addition, the partner company provides proof to the dual@TUHH Coordination Office that the dual student has completed the practical phase.		
Assignment for the Following Curricula	Civil Engineering: Core Qualification: Compulsory Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Electrical Engineering and Information Technology: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Compulsory Energy Systems: Core Qualification: Compulsory Environmental Engineering: Core Qualification: Compulsory Aircraft Systems Engineering: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Information and Communication Systems: Core Qualification: Compulsory International Management and Engineering: Core Qualification: Compulsory Logistics, Infrastructure and Mobility: Core Qualification: Compulsory		

	Aeronautics: Core Qualification: Compulsory Mechanical Engineering - Product Development and Production: Core Qualification: Compulsory Materials Science and Engineering: Core Qualification: Compulsory Materials Science: Core Qualification: Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Biomedical Engineering: Core Qualification: Compulsory Microelectronics and Microsystems: Core Qualification: Compulsory Product Development, Materials and Production: Core Qualification: Compulsory Renewable Energies: Core Qualification: Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory Process Engineering: Core Qualification: Compulsory Water and Environmental Engineering: Core Qualification: Compulsory
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Course L2889: Practical term 3 (dual study program, Master's degree)	
Typ	
Hrs/wk	0
CP	10
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0
Lecturer	Dr. Henning Haschke
Language	DE
Cycle	WiSe/SoSe
Content	<p>Company onboarding process</p> <ul style="list-style-type: none"> Assigning a future professional field of activity as an engineer (M.Sc.) and associated fields of work Extending responsibilities and authorisation of the dual student within the company up to the intended first assignment after completing their studies Working responsibly in a team; project responsibility within own area - as well as across divisions and companies if necessary Scheduling the final practical module with a clear correlation to work structures Internal agreement on a potential topic or innovation project for the Master's dissertation Planning the Master's dissertation within the company in cooperation with TU Hamburg Scheduling the examination phase/subsequent study semester <p>Operational knowledge and skills</p> <ul style="list-style-type: none"> Company-specific: dealing with change, project and team development, responsibility as an engineer in their future field of work (M.Sc.), dealing with complex contexts, frequent and unpredictable changes, developing and implementing innovative solutions Specialising in one field of work (final dissertation) Systemic skills Implementing the university's application recommendations (theory-practice transfer) in corresponding work and task areas across the company <p>Sharing/reflecting on learning</p> <ul style="list-style-type: none"> E-portfolio Relevance of study content and personal specialisation when working as an engineer Relevance of research and innovation when working as an engineer
Literature	<ul style="list-style-type: none"> Studierendenhandbuch betriebliche Dokumente Hochschuleitige Anwendungsempfehlungen zum Theorie-Praxis-Transfer

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
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		
Professional Competence <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"> • using standardized calculation methods in a given context to mechanical properties (modulus, strength) to calculate and evaluate the different materials. • approximate sizing using the network theory of the structural elements implement and evaluate. • selecting appropriate solutions for mechanical recycling problems and sizing example stiffness, corrosion resistance. 		
Personal Competence <i>Social Competence</i>	Students can <ul style="list-style-type: none"> • arrive at funded work results in heterogenius groups and document them. • provide appropriate feedback and handle feedback on their own performance constructively. 		
<i>Autonomy</i>	Students are able to <ul style="list-style-type: none"> - assess their own strengths and weaknesses. - assess their own state of learning in specific terms and to define further work steps on this basis. - assess possible consequences of their professional activity. 		
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 International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechanical Engineering - Product Development and Production: Specialisation Product Development: Elective Compulsory Mechanical Engineering - Product Development and Production: Specialisation Production: Elective Compulsory Mechanical Engineering - Product Development and Production: Specialisation Materials: Compulsory Materials Science and Engineering: Specialisation Engineering Materials: Elective Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory Biomedical Engineering: Specialisation Implants and Endoprotheses: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Materials Science: Elective Compulsory		

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

Course L2614: Structure and properties of fibre-polymer-composites	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Bodo Fiedler
Language	DE/EN
Cycle	SoSe
Content	<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 www.DeepL.com/Translator (free version)</p>
Literature	Hall, Clyne: Introduction to Composite materials, Cambridge University Press Daniel, Ishai: Engineering Mechanics of Composites Materials, Oxford University Press Mallick: Fibre-Reinforced Composites, Marcel Dekker, New York

Course L2613: Structure and properties of fibre-polymer-composites	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Bodo Fiedler
Language	EN
Cycle	SoSe
Content	<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>
Literature	Hall, Clyne: Introduction to Composite materials, Cambridge University Press Daniel, Ishai: Engineering Mechanics of Composites Materials, Oxford University Press 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
Module Responsible	Prof. Anna-Lena Heins		
Admission Requirements	None		
Recommended Previous Knowledge	Knowledge of bioprocess engineering and process engineering at bachelor level		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p>After completion of this module, participants will be able to:</p> <ul style="list-style-type: none"> differentiate between different kinds of bioreactors and describe their key features identify and characterize the peripheral and control systems of bioreactors depict integrated biosystems (bioprocesses including up- and downstream processing) name different sterilization methods and evaluate those in terms of different applications recall and define the advanced methods of modern systems-biological approaches connect the multiple "omics"-methods and evaluate their application for biological questions recall the fundamentals of modeling and simulation of biological networks and biotechnological processes and to discuss their methods 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. 		
<i>Knowledge</i>			
<i>Skills</i>			
Personal Competence			
<i>Social Competence</i>			
<i>Autonomy</i>			
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	120 min		
Assignment for the Following Curricula	Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Process Engineering: Core Qualification: Compulsory		

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

Course L1037: Bioreactors and Biosystems Engineering	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Anna-Lena Heins
Language	EN
Cycle	SoSe
Content	<p>Introduction to Biosystems Engineering (Exercise)</p> <p>Experimental basis and methods for biosystems analysis</p> <ul style="list-style-type: none"> • Introduction to genomics, transcriptomics and proteomics • More detailed treatment of metabolomics • Determination of in-vivo kinetics • Techniques for rapid sampling • Quenching and extraction • Analytical methods for determination of metabolite concentrations <p>Analysis, modelling and simulation of biological networks</p> <ul style="list-style-type: none"> • Metabolic flux analysis • Introduction • Isotope labelling • Elementary flux modes • Mechanistic and structural network models • Regulatory networks • Systems analysis • Structural network analysis • Linear and non-linear dynamic systems • Sensitivity analysis (metabolic control analysis) <p>Modelling and simulation for bioprocess engineering</p> <ul style="list-style-type: none"> • Modelling of bioreactors • Dynamic behaviour of bioprocesses <p>Selected projects for biosystems engineering</p> <ul style="list-style-type: none"> • Miniaturisation of bioreaction systems • Miniplant technology for the integration of biosynthesis and downstream processing • Technical and economic overall assessment of bioproduction processes
Literature	<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	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Johannes Gescher, Prof. Anna-Lena Heins
Language	EN
Cycle	SoSe
Content	<p>Introduction to Biosystems Engineering</p> <p>Experimental basis and methods for biosystems analysis</p> <ul style="list-style-type: none"> • Introduction to genomics, transcriptomics and proteomics • More detailed treatment of metabolomics • Determination of in-vivo kinetics • Techniques for rapid sampling • Quenching and extraction • Analytical methods for determination of metabolite concentrations <p>Analysis, modelling and simulation of biological networks</p> <ul style="list-style-type: none"> • Metabolic flux analysis • Introduction • Isotope labelling • Elementary flux modes • Mechanistic and structural network models • Regulatory networks • Systems analysis • Structural network analysis • Linear and non-linear dynamic systems • Sensitivity analysis (metabolic control analysis) <p>Modelling and simulation for bioprocess engineering</p> <ul style="list-style-type: none"> • Modelling of bioreactors • Dynamic behaviour of bioprocesses <p>Selected projects for biosystems engineering</p> <ul style="list-style-type: none"> • Miniaturisation of bioreaction systems • Miniplant technology for the integration of biosynthesis and downstream processing • Technical and economic overall assessment of bioproduction processes
Literature	<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
Module Responsible	Prof. Mirko Skiborowski			
Admission Requirements	None			
Recommended Previous Knowledge	<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>			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	<p><i>Knowledge</i> 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"> • Introduction to Applied Optimization • Formulation of optimization problems • Linear Optimization • Nonlinear Optimization • Mixed-integer (non)linear optimization • Multi-objective optimization • Global optimization <p><i>Skills</i> 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> <p>Personal Competence</p> <p><i>Social Competence</i> Students are capable of:</p> <ul style="list-style-type: none"> • develop solutions in heterogeneous small groups <p><i>Autonomy</i> Students are capable of:</p> <ul style="list-style-type: none"> • tapping new knowledge on a special subject by literature research 			
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70			
Credit points	6			
Course achievement	Compulsory	Bonus	Form	Description
	No	10 %	Midterm	Bonuspunkte
Examination	Oral exam			
Examination duration and scale	35 min			
Assignment for the Following Curricula	<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 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	
Typ	Integrated Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Mirko Skiborowski
Language	EN
Cycle	SoSe
Content	<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"> - Introduction to Applied Optimization - Formulation of optimization problems - Linear Optimization - Nonlinear Optimization - Mixed-integer (non)linear optimization - Multi-objective optimization - Global optimization
Literature	<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	
Typ	Recitation Section (small)
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Mirko Skiborowski
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	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><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>Personal Competence</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 Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory		

Course L3430: Combined Heat and Power (CHP)	
Type	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	
Type	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	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Ben Norden
Language	DE
Cycle	SoSe
Content	<ol style="list-style-type: none"> 1. Geological Background 2. Hydrothermal targets for geothermal and aquifer storage applications 3. Exploration and petrophysics supporting geothermal planning and site development 4. Geological modeling and usage cases
Literature	<ul style="list-style-type: none"> • Kaltschmitt et al. (eds): Erneuerbare Energien: Systemtechnik, Wirtschaftlichkeit, Umweltaspekte. Springer, 6. Aufl. 2020. • Livescu, S. & Dindoruk, B (eds): Geothermal Energy Engineering, Elsevier, 2025. • Bloemendal, M. et al., 2014: How to achieve optimal and sustainable use of the subsurface for Aquifer Thermal Energy Storage, Energy Policy, Volume 66, https://doi.org/10.1016/j.enpol.2013.11.034.

Module M0900: Examples in Solid Process Engineering				
Courses				
Title		Type	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	<div>Knowledge</div> 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. <div>Skills</div> Students are able to analyze tasks in the field of solids process engineering and to combine suitable subprocesses in a process chain. <div>Personal Competence</div> <div>Social Competence</div> Students are able to discuss technical problems in a scientific manner. <div>Autonomy</div> Students are able to acquire scientific knowledge independently and discuss technical problems in a scientific manner.			
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 Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory			

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

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

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

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

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

Course L3150: System Simulation Modul	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Arne Speerforck, Dr. Johannes Brunnemann
Language	DE
Cycle	WiSe
Content	<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"> • Instruction and modelling of physical processes • Modelling and limits of model • Time constant, stiffness, stability, step size • Terms of object orientated programming • Differential equations of simple systems • Introduction into Modelica • Introduction into simulation tool • Example:Hydraulic systems and heat transfer • Example: System with different subsystems
Literature	<p>[1] Modelica Association: "Modelica Language Specification - Version 3.5", Linköping, Sweden, 2021.</p> <p>[2] OpenModelica: OpenModelica 1.17.0, https://www.openmodelica.org (siehe Download), 2021.</p> <p>[3] M. Tiller: "Modelica by Example", https://book.xogeny.com, 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	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Arne Speerforck, Dr. Johannes Brunnemann
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	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">Basics of thermo dynamicsBasics of fluid dynamicsfluid dynamics chemistry			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence <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. 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 . Students will be able to design and design waste treatment technology equipment.			
<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.			
Personal Competence <i>Social Competence</i>	Students can <ul style="list-style-type: none">respectfully work together as a team and discuss technical tasksparticipate in subject-specific and interdisciplinary discussions,develop cooperated solutionspromote the scientific development and accept professional constructive criticism.			
<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.			
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	120 min			
Assignment for the Following Curricula	Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Environmental Engineering: Specialisation Energy and Resources: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Compulsory Water and Environmental Engineering: Specialisation Cities: Elective Compulsory			

Course L3267: Planning of waste treatment plants	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Rüdiger Siechau
Language	EN
Cycle	WiSe
Content	<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>
Literature	<ul style="list-style-type: none"> • Einführung in die Abfallwirtschaft; Martin Kranert, Klaus Cord-Landwehr (Hrsg.); Vieweg + Teubner Verlag; 2010 • PowerPoint Präsentationen in Stud IP

Course L3265: Recycling technologies and thermal waste treatment	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Kerstin Kuchta
Language	EN
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Introduction, actual state-of-the-art of waste incineration, aims. legal background, reaction principals • basics of incineration processes: waste composition, calorific value, calculation of air demand and flue gas composition • Incineration techniques: grate firing, ash transfer, boiler • Flue gas cleaning: Volume, composition, legal frame work and emission limits, dry treatment, scrubber, de-nox techniques, dioxin elimination, Mercury elimination • Ash treatment: Mass, quality, treatment concepts, recycling, disposal
Literature	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	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Kerstin Kuchta
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	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	Prof. Martin Kaltschmitt			
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			
Professional Competence				
<i>Knowledge</i>				
<i>Skills</i>				
Personal Competence				
<i>Social Competence</i>				
<i>Autonomy</i>				
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84			
Credit points	6			
Course achievement	Compulsory Yes	Bonus 20 %	Form Written elaboration	Description 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 Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Energy Systems: Specialisation Energy Systems: Elective Compulsory Environmental Engineering: Specialisation Energy and Resources: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory			

Course L2414: Second generation biofuels and electricity based fuels	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Martin Kaltschmitt
Language	DE/EN
Cycle	WiSe
Content	<ul style="list-style-type: none"> 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) Origin, production and use of these fuels
Literature	<ul style="list-style-type: none"> Vorlesungsskript

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

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

Course L2415: Sustainability aspects and regulatory framework	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Benedikt Buchspies
Language	DE/EN
Cycle	WiSe
Content	<p>Holistic examination of the different fuel paths with the following main topics, among others:</p> <ul style="list-style-type: none"> • Consideration of the environmental impact of the various alternative fuels • Economic consideration of the different alternative fuels • Regulatory framework for alternative fuels • Certification of alternative fuels • Market introduction models of alternative fuels
Literature	<ul style="list-style-type: none"> • 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 • Richtlinie (EU) 2018/2001 des Europäischen Parlaments und des Rates vom 11. Dezember 2018 zur Förderung der Nutzung von Energie aus erneuerbaren Quellen

Module M2107: Hydrogen Provision Chains				
Courses				
Title		Type	Hrs/wk	CP
Case Studies Hydrogen Provision Chains (L3439)		Project-/problem-based Learning	4	4
Basics of Hydrogen Provision Chains (L3438)		Lecture	2	2
Module Responsible	Prof. Martin Kaltschmitt			
Admission Requirements	None			
Recommended Previous Knowledge	<p>Solar energy utilization</p> <p>Sustainable electrical energy from wind and water</p> <p>Economic and ecological project evaluation</p>			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	<p><i>Knowledge</i> After completing the module, students will be familiar with the basics of hydrogen provision chains, from production and transportation to final provision.</p> <p>This includes both the individual steps within the process chain and the technologies used for this.</p> <p>In addition, students are familiar with various production and transportation processes and their respective advantages and disadvantages.</p> <p><i>Skills</i> After completing the module, students can:</p> <ul style="list-style-type: none"> • Apply the knowledge they have learned to a wide range of issues and evaluate hydrogen supply chains from a technical and economic perspective • Recognize international connections in the hydrogen economy and incorporate them into the evaluation of an overall concept • Systematically document work results by preparing a written paper, giving a presentation and defending the content <p>Personal Competence</p> <p><i>Social Competence</i> After completing the module, students will be able to:</p> <ul style="list-style-type: none"> • Collaborate scientifically in international teams and develop joint solutions • Discuss different positions on energy projects and understand international perspectives on the future of hydrogen supply chains • Organize the cooperation in terms of time and expertise and make sensible use of the different competencies of the group members in order to work together effectively <p><i>Autonomy</i> After completing the module, students will be able to:</p> <ul style="list-style-type: none"> • Independently access sources needed to analyze international hydrogen supply chains, critically evaluate them and use them to address specific issues • Independently coordinate their own work as well as group work, assess their current progress and define necessary work steps • Independently select and implement calculation methods for the evaluation of hydrogen supply chains 			
Workload in Hours				
Credit points				
Course achievement				
Examination				
Examination duration and scale				
Assignment for the Following Curricula	<p>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory</p> <p>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory</p> <p>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory</p>			

Course L3439: Case Studies Hydrogen Provision Chains	
Typ	Project-/problem-based Learning
Hrs/wk	4
CP	4
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Lecturer	Dozenten des SD V
Language	EN
Cycle	WiSe
Content	<p>The hydrogen supply chain case study consists of two mandatory parts:</p> <ul style="list-style-type: none"> • Independent repetition of the fundamentals of hydrogen supply chains through short tests. • A case study in which different aspects of hydrogen supply chains are investigated together with students from our partner universities in the MENA region. This includes: <ul style="list-style-type: none"> ◦ The investigation of a concrete hydrogen supply chain from production in the MENA region to a European port. The different groups will look at different configurations of the supply chain. ◦ Submission of the study results in a written elaboration. ◦ Presentation of the topic with PPT presentation and subsequent discussion in one or two mandatory online closing events.
Literature	<p>Eigenständiges Literaturstudium in der Bibliothek und aus anderen Quellen.</p> <p>Independent study of literature in the library and from other sources.</p>

Course L3438: Basics of Hydrogen Provision Chanis	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dozenten des SD V
Language	EN
Cycle	WiSe
Content	
Literature	

Module M2158: Data Science for Energy System Modelling			
Courses			
Title	Typ	Hrs/wk	CP
Data Science for Energy System Modelling (L3460)	Lecture	4	6
Module Responsible	Dozenten des SD V		
Admission Requirements	None		
Recommended Previous Knowledge	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		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<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"> • Time series analysis of renewable energy sources (wind, solar) and energy demand • GIS-based assessment of renewable energy potentials • Modelling of energy storage and transmission networks • Fundamentals (and revision) of mathematical optimization • Electricity market design and system planning (e.g., merit order, market values, redispatch, nodal pricing) • Sector coupling and demand-side management • Uncertainty analysis and complexity-reduction methods • Implementation of energy system models in Python (e.g., pandas, geopandas, pyomo, cartopy, rasterio, PyPSA, atlite) • Visualization and communication of modelling results <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>Personal Competence</p> <p><i>Social Competence</i> Students are capable of:</p> <ul style="list-style-type: none"> • developing solution strategies to complex energy system modelling problems in heterogeneous small groups, • giving and receiving constructive feedback in project teams and preparing joint results, • engaging in professional discussions and presenting results in a structured manner. <p><i>Autonomy</i> Students are capable of:</p> <ul style="list-style-type: none"> • independently acquiring new knowledge through relevant literature and open-source documentation, • identifying open questions and addressing them using suitable methods, • reflecting on results and solution approaches to make them applicable to future tasks. 		
Workload in Hours			
Credit points			
Course achievement			
Examination	Written elaboration		
Examination duration and scale	10 pages		
Assignment for the Following Curricula	Energy Systems: Specialisation Energy Systems: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory		

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

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	Dr. 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 Knowledge	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.		
Skills	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.		
Personal Competence Social Competence	Students can jointly solve subject related problems in groups. They can present their results effectively within the framework of the problem solving course.		
Autonomy	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.		
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 Electrical Engineering and Information Technology: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory Materials Science and Engineering: Specialisation Nano and Hybrid Materials: Elective Compulsory Microelectronics and Microsystems: Specialisation Microelectronics Complements: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory		

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

Course L0361: Optoelectronics I: Wave Optics (Problem Solving Course)	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Alexander Petrov
Language	EN
Cycle	SoSe
Content	see lecture Optoelectronics 1 - Wave Optics
Literature	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
Module Responsible	Prof. Roland Harig			
Admission Requirements	None			
Recommended Previous Knowledge	Fundamental principles of electrical engineering and measurement technology			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence				
<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.			
Personal Competence				
<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).			
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42			
Credit points	4			
Course achievement	None			
Examination	Oral exam			
Examination duration and scale	45 min			
Assignment for the Following Curricula	Electrical Engineering and Information Technology: Specialisation Control and Power Systems Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory			

Course L1077: Process Measurement Engineering	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe
Content	<ul style="list-style-type: none"> • Introduction to Process Measurement Engineering • Fundamentals <ul style="list-style-type: none"> ◦ Characteristics, Statistics, Calibration ◦ Fourier Transform, Convolution, Cross Correlation, Sampling Theorem • Sensors <ul style="list-style-type: none"> ◦ Distance, Pressure, Strain ◦ Temperature, Infrared • Amplification • Analog to Digital Conversion • Data Transmission and Data Systems • Example: Advanced Process Measurement Systems based on Optical Spectroscopy
Literature	<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&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	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

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			
Professional Competence	<p><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.</p> <p>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).</p> <p><i>Skills</i> Students are capable of</p> <ul style="list-style-type: none">• using standardized calculation methods in a given context to mechanical properties (modulus, strength) to calculate and evaluate the different materials.• approximate sizing using the network theory of the structural elements implement and evaluate.• selecting appropriate solutions for mechanical recycling problems and sizing example stiffness, corrosion resistance. <p>Personal Competence</p> <p><i>Social Competence</i> Students can</p> <ul style="list-style-type: none">• arrive at funded work results in heterogenius groups and document them.• provide appropriate feedback and handle feedback on their own performance constructively. <p><i>Autonomy</i> Students are able to</p> <ul style="list-style-type: none">- assess their own strengths and weaknesses.- assess their own state of learning in specific terms and to define further work steps on this basis.- assess possible consequences of their professional activity.			
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 International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechanical Engineering - Product Development and Production: Specialisation Product Development: Elective Compulsory Mechanical Engineering - Product Development and Production: Specialisation Production: Elective Compulsory Mechanical Engineering - Product Development and Production: Specialisation Materials: Compulsory Materials Science and Engineering: Specialisation Engineering Materials: Elective Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory Biomedical Engineering: Specialisation Implants and Endoprotheses: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Materials Science: Elective Compulsory			

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

Course L2614: Structure and properties of fibre-polymer-composites	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Bodo Fiedler
Language	DE/EN
Cycle	SoSe
Content	<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 www.DeepL.com/Translator (free version)</p>
Literature	Hall, Clyne: Introduction to Composite materials, Cambridge University Press Daniel, Ishai: Engineering Mechanics of Composites Materials, Oxford University Press Mallick: Fibre-Reinforced Composites, Marcel Dekker, New York

Course L2613: Structure and properties of fibre-polymer-composites	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Bodo Fiedler
Language	EN
Cycle	SoSe
Content	<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>
Literature	Hall, Clyne: Introduction to Composite materials, Cambridge University Press Daniel, Ishai: Engineering Mechanics of Composites Materials, Oxford University Press 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
Module Responsible	Prof. Martin Kaltschmitt			
Admission Requirements	None			
Recommended Previous Knowledge	Basics of Electrical Engineering			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	<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>				
Personal Competence				
<i>Social Competence</i>				
<i>Autonomy</i>				
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	120 min			
Assignment for the Following Curricula	Electrical Engineering and Information Technology: Specialisation Control and Power Systems Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory			

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

Course L2054: Power electronics	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Klaus Hoffmann
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	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 Aeronautics: Core Qualification: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory		

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

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

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

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

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

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	Prof. Martin Kaltschmitt			
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			
Professional Competence				
<i>Knowledge</i>				
<i>Skills</i>				
Personal Competence				
<i>Social Competence</i>				
<i>Autonomy</i>				
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84			
Credit points	6			
Course achievement	Compulsory Yes	Bonus 20 %	Form Written elaboration	Description 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 Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Energy Systems: Specialisation Energy Systems: Elective Compulsory Environmental Engineering: Specialisation Energy and Resources: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory			

Course L2414: Second generation biofuels and electricity based fuels	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Martin Kaltschmitt
Language	DE/EN
Cycle	WiSe
Content	<ul style="list-style-type: none"> 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) Origin, production and use of these fuels
Literature	<ul style="list-style-type: none"> Vorlesungsskript

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

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

Course L2415: Sustainability aspects and regulatory framework	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Benedikt Buchspies
Language	DE/EN
Cycle	WiSe
Content	<p>Holistic examination of the different fuel paths with the following main topics, among others:</p> <ul style="list-style-type: none"> • Consideration of the environmental impact of the various alternative fuels • Economic consideration of the different alternative fuels • Regulatory framework for alternative fuels • Certification of alternative fuels • Market introduction models of alternative fuels
Literature	<ul style="list-style-type: none"> • 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 • Richtlinie (EU) 2018/2001 des Europäischen Parlaments und des Rates vom 11. Dezember 2018 zur Förderung der Nutzung von Energie aus erneuerbaren Quellen

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

Course L3150: System Simulation Modul	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Arne Speerforck, Dr. Johannes Brunnemann
Language	DE
Cycle	WiSe
Content	<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"> • Instruction and modelling of physical processes • Modelling and limits of model • Time constant, stiffness, stability, step size • Terms of object orientated programming • Differential equations of simple systems • Introduction into Modelica • Introduction into simulation tool • Example:Hydraulic systems and heat transfer • Example: System with different subsystems
Literature	<p>[1] Modelica Association: "Modelica Language Specification - Version 3.5", Linköping, Sweden, 2021.</p> <p>[2] OpenModelica: OpenModelica 1.17.0, https://www.openmodelica.org (siehe Download), 2021.</p> <p>[3] M. Tiller: "Modelica by Example", https://book.xogeny.com, 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	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Arne Speerforck, Dr. Johannes Brunnemann
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M2107: Hydrogen Provision Chains				
Courses				
Title		Type	Hrs/wk	CP
Case Studies Hydrogen Provision Chains (L3439)		Project-/problem-based Learning	4	4
Basics of Hydrogen Provision Chains (L3438)		Lecture	2	2
Module Responsible	Prof. Martin Kaltschmitt			
Admission Requirements	None			
Recommended Previous Knowledge	<p>Solar energy utilization</p> <p>Sustainable electrical energy from wind and water</p> <p>Economic and ecological project evaluation</p>			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	<p><i>Knowledge</i> After completing the module, students will be familiar with the basics of hydrogen provision chains, from production and transportation to final provision.</p> <p>This includes both the individual steps within the process chain and the technologies used for this.</p> <p>In addition, students are familiar with various production and transportation processes and their respective advantages and disadvantages.</p> <p><i>Skills</i> After completing the module, students can:</p> <ul style="list-style-type: none"> • Apply the knowledge they have learned to a wide range of issues and evaluate hydrogen supply chains from a technical and economic perspective • Recognize international connections in the hydrogen economy and incorporate them into the evaluation of an overall concept • Systematically document work results by preparing a written paper, giving a presentation and defending the content <p><i>Personal Competence</i></p> <p><i>Social Competence</i> After completing the module, students will be able to:</p> <ul style="list-style-type: none"> • Collaborate scientifically in international teams and develop joint solutions • Discuss different positions on energy projects and understand international perspectives on the future of hydrogen supply chains • Organize the cooperation in terms of time and expertise and make sensible use of the different competencies of the group members in order to work together effectively <p><i>Autonomy</i> After completing the module, students will be able to:</p> <ul style="list-style-type: none"> • Independently access sources needed to analyze international hydrogen supply chains, critically evaluate them and use them to address specific issues • Independently coordinate their own work as well as group work, assess their current progress and define necessary work steps • Independently select and implement calculation methods for the evaluation of hydrogen supply chains 			
Workload in Hours				
Credit points				
Course achievement				
Examination				
Examination duration and scale				
Assignment for the Following Curricula	<p>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory</p> <p>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory</p> <p>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory</p>			

Course L3439: Case Studies Hydrogen Provision Chains	
Typ	Project-/problem-based Learning
Hrs/wk	4
CP	4
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Lecturer	Dozenten des SD V
Language	EN
Cycle	WiSe
Content	<p>The hydrogen supply chain case study consists of two mandatory parts:</p> <ul style="list-style-type: none"> • Independent repetition of the fundamentals of hydrogen supply chains through short tests. • A case study in which different aspects of hydrogen supply chains are investigated together with students from our partner universities in the MENA region. This includes: <ul style="list-style-type: none"> ◦ The investigation of a concrete hydrogen supply chain from production in the MENA region to a European port. The different groups will look at different configurations of the supply chain. ◦ Submission of the study results in a written elaboration. ◦ Presentation of the topic with PPT presentation and subsequent discussion in one or two mandatory online closing events.
Literature	<p>Eigenständiges Literaturstudium in der Bibliothek und aus anderen Quellen.</p> <p>Independent study of literature in the library and from other sources.</p>

Course L3438: Basics of Hydrogen Provision Chanis	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dozenten des SD V
Language	EN
Cycle	WiSe
Content	
Literature	

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
Module Responsible	Prof. Christian Becker			
Admission Requirements	None			
Recommended Previous Knowledge	Fundamentals of Electrical Engineering, Introduction to Control Systems, Mathematics I, II, III Electrical Power Systems I Electrical Power Systems II			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	Students are able to explain in detail and critically evaluate methods and technologies for operation of smart grids (i.e. intelligent distribution grids). 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. The students can participate in specialized and interdisciplinary discussions, advance ideas and represent their own work results in front of others. Students can independently tap knowledge of the emphasis of the lectures and apply it within further research activities.			
<i>Knowledge</i>				
<i>Skills</i>				
Personal Competence				
<i>Social Competence</i>				
<i>Autonomy</i>				
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70			
Credit points	6			
Course achievement	None			
Examination	Presentation			
Examination duration and scale	30 min			
Assignment for the Following Curricula	Electrical Engineering and Information Technology: Specialisation Control and Power Systems Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Energy Systems: Specialisation Energy Systems: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory			

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

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

Module M2175: Transport Processes				
Courses				
Title	Typ		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			
Professional Competence	<p><i>Knowledge</i> Students are able to:</p> <ul style="list-style-type: none"> 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. explain the main transport laws and their application as well as the limits of application. describe how transport coefficients for heat- and mass transfer can be derived experimentally. compare different multiphase reactors like trickle bed reactors, pipe reactors, stirring tanks and bubble column reactors. 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. <p><i>Skills</i> The students are able to:</p> <ul style="list-style-type: none"> optimize multiphase reactors by using mass- and energy balances, use transport processes for the design of technical processes, to choose a multiphase reactor for a specific application. <p>Personal Competence</p> <p><i>Social Competence</i> The students are able to discuss in international teams in english and develop an approach under pressure of time.</p> <p><i>Autonomy</i> Students are able to define independently tasks, to solve the problem "design of a multiphase reactor". The knowledge that s necessary is worked out by the students themselves on the basis of the existing knowledge from the lecture. The students are able to decide by themselves what kind of equation and model is applicable to their certain problem. They are able to organize their own team and to define priorities for different tasks.</p>			
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84			
Credit points	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			
Assignment for the Following Curricula	Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Process Engineering: Core Qualification: Compulsory			

Course L0104: Multiphase Flows	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	EN
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Interfaces in MPF (boundary layers, surfactants) • Hydrodynamics & pressure drop in Film Flows • Hydrodynamics & pressure drop in Gas-Liquid Pipe Flows • Hydrodynamics & pressure drop in Bubbly Flows • Mass Transfer in Film Flows • Mass Transfer in Gas-Liquid Pipe Flows • Mass Transfer in Bubbly Flows • Reactive mass Transfer in Multiphase Flows • Film Flow: Application Trickle Bed Reactors • Pipe Flow: Application Turbular Reactors • Bubbly Flow: Application Bubble Column Reactors
Literature	<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 & 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	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	EN
Cycle	WiSe
Content	<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"> • collect and discuss material properties and equations for design from the literature, • calculate the optimal hydrodynamic design, • check the plausibility of the results critically, • write an exposé with the results. <p>This exposé will be used as basis for the discussion within the oral group examen of each team.</p>
Literature	<p>Bird, R.B.; Stewart, W.R.; Lightfoot, E.N.: Transport Phenomena, John Wiley & 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	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	EN
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Introduction - Transport Processes in Chemical Engineering • Molecular Heat- and Mass Transfer: Applications of Fourier's and Fick's Law • Convective Heat and Mass Transfer: Applications in Process Engineering • Unsteady State Transport Processes: Cooling & Drying • Transport at fluidic Interfaces: Two Film, Penetration, Surface Renewal • Transport Laws & Balance Equations with turbulence, sinks and sources • Experimental Determination of Transport Coefficients • Design and Scale Up of Reactors for Heat- and Mass Transfer • Reactive Mass Transfer • Processes with Phase Changes - Evaporization and Condensation • Radiative Heat Transfer - Fundamentals • Radiative Heat Transfer - Solar Energy
Literature	<ol style="list-style-type: none"> 1. Baehr, Stephan: Heat and Mass Transfer, Wiley 2002. 2. Bird, Stewart, Lightfoot: Transport Phenomena, Springer, 2000. 3. John H. Lienhard: A Heat Transfer Textbook, Phlogiston Press, Cambridge Massachusetts, 2008. 4. Myers: Analytical Methods in Conduction Heat Transfer, McGraw-Hill, 1971. 5. Incropera, De Witt: Fundamentals of Heat and Mass Transfer, Wiley, 2002. 6. Beek, Muttzall: Transport Phenomena, Wiley, 1983. 7. Crank: The Mathematics of Diffusion, Oxford, 1995. 8. Madhusudana: Thermal Contact Conductance, Springer, 1996. 9. Treybal: Mass-Transfer-Operation, McGraw-Hill, 1987.

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 <i>Knowledge</i>	<p>Th</p> <p>After completing the module, students can...</p> <ul style="list-style-type: none"> 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; explain and evaluate different types of seaport terminals and their specific characteristics (cargo, transshipment technologies, logistic functional areas); 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; identify future developments and trends regarding the planning and control of innovative seaport terminals and discuss them in a problem-oriented manner. 			
<i>Skills</i>	<p>After completing the module, students will be able to...</p> <ul style="list-style-type: none"> recognize functional areas in ports and seaport terminals; define and evaluate suitable operating systems for container terminals; 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; reliably estimate which boundary conditions influence common logistics indicators in the static planning of selected terminal types and to what extent. 			
Personal Competence <i>Social Competence</i>	<p>After completing the module, students can...</p> <ul style="list-style-type: none"> transfer the acquired knowledge to further questions of port logistics; discuss and successfully organize extensive task packages in small groups; in small groups, document work results in writing in an understandable form and present them to an appropriate extent. 			
<i>Autonomy</i>	<p>After completing the module, the students are able to...</p> <ul style="list-style-type: none"> research and select specialist literature, including standards, guidelines and journal papers, and to develop the contents independently; submit own parts in an extensive written elaboration in small groups in due time and to present them jointly within a fixed time frame. 			
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 International Management and Engineering: Specialisation II. Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory			

	Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Elective Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Maritime Technology: Elective Compulsory
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Course L0686: Port Logistics	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Carlos Jahn
Language	DE
Cycle	SoSe
Content	<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"> • Instruction of structures and processes in the port • Planning, control, implementation and monitoring of material and information flows in the port • Fundamentals of different terminals, characteristic layouts and the technical equipment used • Handling of current issues in port logistics
Literature	<ul style="list-style-type: none"> • Biebig, Peter and Althof, Wolfgang and Wagener, Norbert (2017). Seeverkehrswirtschaft: Kompendium. De Gruyter: Berlin/Boston • Böse, Jürgen W. (2020). Handbook of Terminal Planning. Springer: New York • Jahn, Carlos and Saxe, Sebastian (2017). Digitalization of Seaports - Visions of the Future. Fraunhofer Verlag: Stuttgart • Kummer, Sebastian (2019). Einführung in die Verkehrswirtschaft. UTB: Stuttgart and s.l. • Mi, Weijian and Liu, Yuan (2022). Smart Ports. Springer: Singapore • UNCTAD (2024). Review of Maritime Transport 2024. UN: United Nations Publications, New York, USA • Zhang, Xufan and Roe, Michael (2019). Maritime Container Port Security. Palgrave Macmillan Cham: Basingstoke

Course L1473: Port Logistics	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Carlos Jahn
Language	DE
Cycle	SoSe
Content	<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>
Literature	<ul style="list-style-type: none"> • Biebig, Peter and Althof, Wolfgang and Wagener, Norbert (2017). Seeverkehrswirtschaft: Kompendium. De Gruyter: Berlin/Boston • Böse, Jürgen W. (2020). Handbook of Terminal Planning. Springer: New York • Jahn, Carlos and Saxe, Sebastian (2017). Digitalization of Seaports - Visions of the Future. Fraunhofer Verlag: Stuttgart • Kummer, Sebastian (2019). Einführung in die Verkehrswirtschaft. UTB: Stuttgart and s.l. • Mi, Weijian and Liu, Yuan (2022). Smart Ports. Springer: Singapore • UNCTAD (2024). Review of Maritime Transport 2024. UN: United Nations Publications, New York, USA • Zhang, Xufan and Roe, Michael (2019). Maritime Container Port Security. Palgrave Macmillan Cham: Basingstoke

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">• present the actors involved in the maritime transport chain with regard to their typical tasks;• name common cargo types in shipping and classify cargo to the corresponding categories;• explain operating forms in maritime shipping, transport options and management in transport networks;• weigh the advantages and disadvantages of the various modes of hinterland transport and apply them in practice;• estimate the potential of digitisation in maritime shipping.</div><div><div>Skills</div><div>The students are able to...<ul style="list-style-type: none">• determine the mode of transport, actors and functions of the actors in the maritime supply chain;• identify possible cost drivers in a transport chain and recommend appropriate proposals for cost reduction;• record, map and systematically analyse material and information flows of a maritime logistics chain, identify possible problems and recommend solutions;• perform risk assessments of human disruptions to the supply chain;• analyse accidents in the field of maritime logistics and evaluating their relevance in everyday life;• deal with current research topics in the field of maritime logistics in a differentiated way;• plan the deployment of a fleet based on scenarios;• apply different process modelling methods in a hitherto unknown field of activity and to work out the respective advantages.</div></div></div>				
Personal Competence					
<div><div>Social Competence</div><div>The students are able to...<ul style="list-style-type: none">• discuss and organise extensive work packages in groups;• document and present the elaborated results.</div><div><div>Autonomy</div><div>The students are capable to...<ul style="list-style-type: none">• research and select technical literature, including standards and guidelines;• submit own shares in an extensive written elaboration in small groups in due time.</div></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 International Management and Engineering: Specialisation II. Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Maritime Technology: Elective Compulsory				

Course L0063: Maritime Transport	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Carlos Jahn
Language	DE
Cycle	SoSe
Content	<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>
Literature	<ul style="list-style-type: none"> Rodrigue, Jean-Paul. Geography of Transport Systems. London New York: Routledge, 2020. Geisler, Alexander and Johns, Dirk Max (2018). SEE-SCHIFF-LADUNG: Fachbuch für Schifffahrtskaufleute : von Praktikern für Praktiker. von Stern-Verlag KG: Lüneburg. Huber, Wolfgang (2018). Überseecontainer beladen. Verlag Heinrich Vogel. Jensen, Rune Møller and Pacino, Dario and Ajspur, Mai Lise and Vesterdal, Claus (2018). Container vessel stowage planning. Weilbach. UNCTAD (2024). Review of Maritime Transport 2024. UN: United Nations Publications, New York, USA.

Course L0064: Maritime Transport	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Carlos Jahn
Language	DE
Cycle	SoSe
Content	<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>
Literature	<ul style="list-style-type: none"> Brinkmann, Birgitt. Seehäfen: Planung und Entwurf. Berlin Heidelberg: Springer-Verlag, 2005. Böse, Jürgen W. Handbook of Terminal Planning. Springer, Cham, 2020. Lieberuth, Thomas. Prozessmanagement in Einkauf und Logistik - Instrumente und Methoden für das Supply Chain Process Management, Springer Gabler Wiesbaden, 2024. Laue, Ralf; Koschmider, Agnes; Fahland, Dirk. Prozessmanagement und Process-Mining: Grundlagen, Walter de Gruyter GmbH & Co KG, 2020.

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			
Professional Competence <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">• using standardized calculation methods in a given context to mechanical properties (modulus, strength) to calculate and evaluate the different materials.• approximate sizing using the network theory of the structural elements implement and evaluate.• selecting appropriate solutions for mechanical recycling problems and sizing example stiffness, corrosion resistance.			
Personal Competence <i>Social Competence</i>	Students can			
	<ul style="list-style-type: none">• arrive at funded work results in heterogenius groups and document them.• provide appropriate feedback and handle feedback on their own performance constructively.			
<i>Autonomy</i>	Students are able to			
	<ul style="list-style-type: none">- assess their own strengths and weaknesses.- assess their own state of learning in specific terms and to define further work steps on this basis.- assess possible consequences of their professional activity.			
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 International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechanical Engineering - Product Development and Production: Specialisation Product Development: Elective Compulsory Mechanical Engineering - Product Development and Production: Specialisation Production: Elective Compulsory Mechanical Engineering - Product Development and Production: Specialisation Materials: Compulsory Materials Science and Engineering: Specialisation Engineering Materials: Elective Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory Biomedical Engineering: Specialisation Implants and Endoprotheses: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Materials Science: Elective Compulsory			

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

Course L2614: Structure and properties of fibre-polymer-composites	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Bodo Fiedler
Language	DE/EN
Cycle	SoSe
Content	<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 www.DeepL.com/Translator (free version)</p>
Literature	Hall, Clyne: Introduction to Composite materials, Cambridge University Press Daniel, Ishai: Engineering Mechanics of Composites Materials, Oxford University Press Mallick: Fibre-Reinforced Composites, Marcel Dekker, New York

Course L2613: Structure and properties of fibre-polymer-composites	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Bodo Fiedler
Language	EN
Cycle	SoSe
Content	<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>
Literature	Hall, Clyne: Introduction to Composite materials, Cambridge University Press Daniel, Ishai: Engineering Mechanics of Composites Materials, Oxford University Press 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
Module Responsible	Prof. Mirko Skiborowski			
Admission Requirements	None			
Recommended Previous Knowledge	<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>			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence <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"> • Introduction to Applied Optimization • Formulation of optimization problems • Linear Optimization • Nonlinear Optimization • Mixed-integer (non)linear optimization • Multi-objective optimization • Global optimization 			
<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>			
Personal Competence <i>Social Competence</i>	<p>Students are capable of:</p> <ul style="list-style-type: none"> • develop solutions in heterogeneous small groups 			
<i>Autonomy</i>	<p>Students are capable of:</p> <ul style="list-style-type: none"> • tapping new knowledge on a special subject by literature research 			
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70			
Credit points	6			
Course achievement	Compulsory	Bonus	Form	Description
	No	10 %	Midterm	Bonuspunkte
Examination	Oral exam			
Examination duration and scale	35 min			
Assignment for the Following Curricula	<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 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	
Typ	Integrated Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Mirko Skiborowski
Language	EN
Cycle	SoSe
Content	<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"> - Introduction to Applied Optimization - Formulation of optimization problems - Linear Optimization - Nonlinear Optimization - Mixed-integer (non)linear optimization - Multi-objective optimization - Global optimization
Literature	<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	
Typ	Recitation Section (small)
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Mirko Skiborowski
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	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 Aeronautics: Core Qualification: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory		

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

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

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

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

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

Module M0528: Maritime Technology and Offshore Wind Parks			
Courses			
Title	Typ	Hrs/wk	CP
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
Module Responsible	Prof. Moustafa Abdel-Maksoud		
Admission Requirements	None		
Recommended Previous Knowledge	<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>		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence <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"> describe the different aspects and topics in Maritime Technology, apply existing methods to problems in Maritime Technology, discuss limitations in present day approaches and perspectives in the future. <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"> Show present research questions in the field Explain the present state of the art for the topics considered Apply given methodology to approach given problems Evaluate the limits of the present methods Identify possibilities to extend present methods Evaluate the feasibility of further developments 		
Personal Competence <i>Skills</i> <i>Social Competence</i> <i>Autonomy</i>			
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	180 min		
Assignment for the Following Curricula	<p>Energy Systems: Specialisation Marine Engineering: 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	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Walter Kuehnlein
Language	DE/EN
Cycle	WiSe
Content	<p>1. Introduction</p> <ul style="list-style-type: none"> • Ocean Engineering and Marine Research • The potentials of the seas • Industries and occupational structures <p>2. Coastal and offshore Environmental Conditions</p> <ul style="list-style-type: none"> • Physical and chemical properties of sea water and sea ice • Flows, waves, wind, ice • Biosphere <p>3. Response behavior of Technical Structures</p> <p>4. Maritime Systems and Technologies</p> <ul style="list-style-type: none"> • General Design and Installation of Offshore-Structures • Geophysical and Geotechnical Aspects • Fixed and Floating Platforms • Mooring Systems, Risers, Pipelines • Energy conversion: Wind, Waves, Tides
Literature	<ul style="list-style-type: none"> • Chakrabarti, S., Handbook of Offshore Engineering, vol. I/II, Elsevier 2005. • Gerwick, B.C., Construction of Marine and Offshore Structures, CRC-Press 1999. • Wagner, P., Meerestechnik, Ernst&Sohn 1990. • Clauss, G., Meerestechnische Konstruktionen, Springer 1988. • Knauss, J.A., Introduction to Physical Oceanography, Waveland 2005. • Wright, J. et al., Waves, Tides and Shallow-Water Processes, Butterworth 2006. • Faltinsen, O.M., Sea Loads on Ships and Offshore Structures, Cambridge 1999.

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

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

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	Prof. Martin Kaltschmitt			
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			
Professional Competence	<div>Knowledge</div> <p>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.</p> <div>Skills</div> <p>After successfully participating, the students are able to solve simulation and application tasks of renewable energy technology:</p> <ul style="list-style-type: none">• Module-spanning solutions for the design and presentation of fuel production processes resp. the fuel provision chains• Comprehensive analysis of various fuel production options in technical, ecological and economic terms <p>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.</p> <div>Personal Competence</div> <div>Social Competence</div> <p>The students can discuss scientific tasks in a subject-specific and interdisciplinary way and develop joint solutions.</p> <div>Autonomy</div> <p>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.</p>			
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 Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Energy Systems: Specialisation Energy Systems: Elective Compulsory Environmental Engineering: Specialisation Energy and Resources: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory			

Course L2414: Second generation biofuels and electricity based fuels	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Martin Kaltschmitt
Language	DE/EN
Cycle	WiSe
Content	<ul style="list-style-type: none"> 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) Origin, production and use of these fuels
Literature	<ul style="list-style-type: none"> Vorlesungsskript

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

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

Course L2415: Sustainability aspects and regulatory framework	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Benedikt Buchspies
Language	DE/EN
Cycle	WiSe
Content	<p>Holistic examination of the different fuel paths with the following main topics, among others:</p> <ul style="list-style-type: none"> • Consideration of the environmental impact of the various alternative fuels • Economic consideration of the different alternative fuels • Regulatory framework for alternative fuels • Certification of alternative fuels • Market introduction models of alternative fuels
Literature	<ul style="list-style-type: none"> • 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 • Richtlinie (EU) 2018/2001 des Europäischen Parlaments und des Rates vom 11. Dezember 2018 zur Förderung der Nutzung von Energie aus erneuerbaren Quellen

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

Course L3150: System Simulation Modul	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Arne Speerforck, Dr. Johannes Brunnemann
Language	DE
Cycle	WiSe
Content	<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"> • Instruction and modelling of physical processes • Modelling and limits of model • Time constant, stiffness, stability, step size • Terms of object orientated programming • Differential equations of simple systems • Introduction into Modelica • Introduction into simulation tool • Example:Hydraulic systems and heat transfer • Example: System with different subsystems
Literature	<p>[1] Modelica Association: "Modelica Language Specification - Version 3.5", Linköping, Sweden, 2021.</p> <p>[2] OpenModelica: OpenModelica 1.17.0, https://www.openmodelica.org (siehe Download), 2021.</p> <p>[3] M. Tiller: "Modelica by Example", https://book.xogeny.com, 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	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Arne Speerforck, Dr. Johannes Brunnemann
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M2107: Hydrogen Provision Chains				
Courses				
Title		Type	Hrs/wk	CP
Case Studies Hydrogen Provision Chains (L3439)		Project-/problem-based Learning	4	4
Basics of Hydrogen Provision Chains (L3438)		Lecture	2	2
Module Responsible	Prof. Martin Kaltschmitt			
Admission Requirements	None			
Recommended Previous Knowledge	<p>Solar energy utilization</p> <p>Sustainable electrical energy from wind and water</p> <p>Economic and ecological project evaluation</p>			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	<p><i>Knowledge</i> After completing the module, students will be familiar with the basics of hydrogen provision chains, from production and transportation to final provision.</p> <p>This includes both the individual steps within the process chain and the technologies used for this.</p> <p>In addition, students are familiar with various production and transportation processes and their respective advantages and disadvantages.</p> <p><i>Skills</i> After completing the module, students can:</p> <ul style="list-style-type: none"> • Apply the knowledge they have learned to a wide range of issues and evaluate hydrogen supply chains from a technical and economic perspective • Recognize international connections in the hydrogen economy and incorporate them into the evaluation of an overall concept • Systematically document work results by preparing a written paper, giving a presentation and defending the content <p>Personal Competence</p> <p><i>Social Competence</i> After completing the module, students will be able to:</p> <ul style="list-style-type: none"> • Collaborate scientifically in international teams and develop joint solutions • Discuss different positions on energy projects and understand international perspectives on the future of hydrogen supply chains • Organize the cooperation in terms of time and expertise and make sensible use of the different competencies of the group members in order to work together effectively <p><i>Autonomy</i> After completing the module, students will be able to:</p> <ul style="list-style-type: none"> • Independently access sources needed to analyze international hydrogen supply chains, critically evaluate them and use them to address specific issues • Independently coordinate their own work as well as group work, assess their current progress and define necessary work steps • Independently select and implement calculation methods for the evaluation of hydrogen supply chains 			
Workload in Hours				
Credit points				
Course achievement				
Examination				
Examination duration and scale				
Assignment for the Following Curricula	<p>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory</p> <p>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory</p> <p>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory</p>			

Course L3439: Case Studies Hydrogen Provision Chains	
Typ	Project-/problem-based Learning
Hrs/wk	4
CP	4
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Lecturer	Dozenten des SD V
Language	EN
Cycle	WiSe
Content	<p>The hydrogen supply chain case study consists of two mandatory parts:</p> <ul style="list-style-type: none"> • Independent repetition of the fundamentals of hydrogen supply chains through short tests. • A case study in which different aspects of hydrogen supply chains are investigated together with students from our partner universities in the MENA region. This includes: <ul style="list-style-type: none"> ◦ The investigation of a concrete hydrogen supply chain from production in the MENA region to a European port. The different groups will look at different configurations of the supply chain. ◦ Submission of the study results in a written elaboration. ◦ Presentation of the topic with PPT presentation and subsequent discussion in one or two mandatory online closing events.
Literature	<p>Eigenständiges Literaturstudium in der Bibliothek und aus anderen Quellen.</p> <p>Independent study of literature in the library and from other sources.</p>

Course L3438: Basics of Hydrogen Provision Chanis	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dozenten des SD V
Language	EN
Cycle	WiSe
Content	
Literature	

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
Module Responsible	Prof. Christian Becker			
Admission Requirements	None			
Recommended Previous Knowledge	Fundamentals of Electrical Engineering, Introduction to Control Systems, Mathematics I, II, III Electrical Power Systems I Electrical Power Systems II			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	Students are able to explain in detail and critically evaluate methods and technologies for operation of smart grids (i.e. intelligent distribution grids). 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.			
<i>Knowledge</i>				
<i>Skills</i>				
Personal Competence				
<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.			
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70			
Credit points	6			
Course achievement	None			
Examination	Presentation			
Examination duration and scale	30 min			
Assignment for the Following Curricula	Electrical Engineering and Information Technology: Specialisation Control and Power Systems Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Energy Systems: Specialisation Energy Systems: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory			

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

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

Module M2158: Data Science for Energy System Modelling			
Courses			
Title	Typ	Hrs/wk	CP
Data Science for Energy System Modelling (L3460)	Lecture	4	6
Module Responsible	Dozenten des SD V		
Admission Requirements	None		
Recommended Previous Knowledge	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		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<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"> • Time series analysis of renewable energy sources (wind, solar) and energy demand • GIS-based assessment of renewable energy potentials • Modelling of energy storage and transmission networks • Fundamentals (and revision) of mathematical optimization • Electricity market design and system planning (e.g., merit order, market values, redispatch, nodal pricing) • Sector coupling and demand-side management • Uncertainty analysis and complexity-reduction methods • Implementation of energy system models in Python (e.g., pandas, geopandas, pyomo, cartopy, rasterio, PyPSA, atlite) • Visualization and communication of modelling results <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>Personal Competence</p> <p><i>Social Competence</i> Students are capable of:</p> <ul style="list-style-type: none"> • developing solution strategies to complex energy system modelling problems in heterogeneous small groups, • giving and receiving constructive feedback in project teams and preparing joint results, • engaging in professional discussions and presenting results in a structured manner. <p><i>Autonomy</i> Students are capable of:</p> <ul style="list-style-type: none"> • independently acquiring new knowledge through relevant literature and open-source documentation, • identifying open questions and addressing them using suitable methods, • reflecting on results and solution approaches to make them applicable to future tasks. 		
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56		
Credit points	6		
Course achievement	None		
Examination	Written elaboration		
Examination duration and scale	10 pages		
Assignment for the Following Curricula	Energy Systems: Specialisation Energy Systems: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory		

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

Thesis

Module M1801: Master thesis (dual study program)

Courses

Title	Typ	Hrs/wk	CP
Module Responsible	Professoren der TUHH		
Admission Requirements	None		
Recommended Previous Knowledge			
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence			
<i>Knowledge</i>	Dual students ... <ul style="list-style-type: none"> ... use the specialised knowledge (facts, theories and methods) from their field of study and the acquired professional knowledge confidently to deal with technical and practical professional issues. ... can explain the relevant approaches and terminologies in depth in one or more of their subject's specialist areas, describe current developments and take a critical stance. ... formulate their own research assignment to tackle a professional problem and contextualise it within their subject area. They ascertain the current state of research and critically assess it. 		
<i>Skills</i>	Dual students ... <ul style="list-style-type: none"> ... can select suitable methods for the respective subject-related professional problem, apply them and develop them further as required. ... assess knowledge and methods acquired during their studies (including practical phases) and apply their expertise to complex and/or incompletely defined problems in a solution- and application-oriented manner. ... acquire new academic knowledge in their subject area and critically evaluate it. 		
Personal Competence			
<i>Social Competence</i>	Dual students ... <ul style="list-style-type: none"> ... can present a professional problem in the form of an academic question in a structured, comprehensible and factually correct manner, both in writing and orally, for a specialist audience and for professional stakeholders. ... answer questions as part of a professional discussion in an expert, appropriate manner. They represent their own points of view and assessments convincingly. 		
<i>Autonomy</i>	Dual students ... <ul style="list-style-type: none"> ... can structure their own project into work packages, work through them at an academic level and reflect on them with regard to feasible courses of action for professional practice. ... work in-depth in a partially unknown area within the discipline and acquire the information required to do so. ... apply the techniques of academic work comprehensively in their own research work when dealing with an operational problem and question. 		
Workload in Hours	Independent Study Time 900, Study Time in Lecture 0		
Credit points	30		
Course achievement	None		
Examination	Thesis		
Examination duration and scale	According to General Regulations		
Assignment for the Following Curricula	Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computational Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Data Science: Thesis: Compulsory Electrical Engineering and Information Technology: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Computer Science in Engineering: Thesis: Compulsory Information and Communication Systems: Thesis: Compulsory International Management and Engineering: 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 Materials Science: Thesis: Compulsory		

Mechanical Engineering and Management: Thesis: Compulsory
Mechatronics: Thesis: Compulsory
Biomedical Engineering: Thesis: Compulsory
Microelectronics and Microsystems: Thesis: Compulsory
Product Development, Materials and Production: Thesis: Compulsory
Renewable Energies: Thesis: Compulsory
Naval Architecture and Ocean Engineering: Thesis: Compulsory
Naval Architecture and Ocean Engineering: Thesis: Compulsory
Theoretical Mechanical Engineering: Thesis: Compulsory
Process Engineering: Thesis: Compulsory
Water and Environmental Engineering: Thesis: Compulsory