Technische Hochschule Ingolstadt

Program and Course Description

WS 2025/26

Energy Systems and Renewable Energies (SPO WS 21/22)

Bachelor

Study regulation: WS 21/22

as per: 18.07.2025

Content

1 Overview

Name of the study course	Energy Systems and Renewable Energies
Degree & type of program	Bachelor of Engineering (B.Eng.); fulltime course
First start of program	October 1, 2021
Programme duration	7 semesters (210 ECTS, 150 SWS)
Place of study	THI Ingolstadt
Teaching Language	English

Academic Director:

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2 Introduction

2.1 Objective of the course

The Energy Systems and Renewable Energies degree program aims to provide an education based on scientific knowledge and methods through practice - oriented teaching, which enables students to work independently as engineers in the field of energy systems/energy technology.

Students will be able to develop, design and implement future - oriented products and services in an international environment with a responsible and sustainable use of resources.

In addition, the program promotes personal development, cooperation in international teams in which English is the language of communication and the ability to work in a multicultural environment.

Social and methodological skills are taught in addition to technical skills in order to promote personal development and leadership qualities.

The social skills acquired in internships, seminars or the project enable students to work as part of a team or lead a project group.

In view of the breadth and diversity of the field of energy systems/energy technology, students are to be enabled to quickly familiarise themselves with one of the numerous fields of application through comprehensive training in the basic subjects.

In the course of their studies, students learn in detail about different systems, such as building energy systems and industrial supply systems, the various regenerative energy sources, the corresponding energy technology, new concepts for mobility, the networking of all areas from generation to consumption as well as the economic assessment of energy supply concepts. Special areas such as Artificial Intelligence are also integrated into several subjects in the curriculum.

International aspects also prepare and enable students to face the increasingly global challenges and demands and also to hold their own in global markets.

The completed bachelor's program also provides the basis for further academic qualification in a subsequent master's program.

Graduates of the course are prepared for specialist and managerial tasks in the following areas:

- Sustainable energy generation and distribution
- Development, production and operation of energy technology plants and energy systems
- Planning of energy systems and energy consulting
- In Germany and worldwide, as multipliers, so to speak, who make a contribution to global activities against the climate crisis with their acquired knowledge and skills

Description of the program / Contents

Limiting climate change is one of the biggest worldwide challenges of the 21st century. Implementing smart, integrated energy solutions and developing new and clean technologies helps meeting this key objective.

Therefore there is a need for engineers specialized on Energy Systems and Renewable Energies and the integration of these technologies in the energy system.

The Bachelor "Energy Systems and Renewable Energies" meets these demands. This bachelor is fully taught in English and welcomes both German and international students.

Main Contents:

- Specialized contents in renewable energies with high practical orientation
- Science Fundamentals like Thermodynamics, Mechanics, Fluid-Mechanics, Electrical Engineering
- Fundamentals of Mechanical Engineering: Mechanical Design, CAD, Material Science, Product Development
- Energy Fundamentals (Generation): Solar Energy, Wind Energy, Hydro Energy, Biomass, Geothermal Energy
- Energy Systems: Smart Cities, Industry Supply Systems, Smart Buildings; Energy Markets, Sector Coupling, Artificial intelligence
- Actuators in Energy Systems: Combined Heat and Power Plants, Heat Pumps, Batteries, Fuel Cells
- New energy carriers and conversions: E-Mobility, Biomethane, Hydrogen, Power to Gas, Power to Heat

At the same time, the students acquire the ability to carry out economic assessments of energy supply concepts in order to prepare investment decisions. These economic analyses together with the knowledge of entrepreneurship enable them to found and/or lead a company.

As a student, you will get an insight into various methods of digital engineering. You will use 3D-CAD (computer-aided design) software for mechanical design. You will learn to simulate thermodynamic and fluid dynamic processes, energy-technical plants and energy systems with commercial simulation tools.

All these innovative contents will allow the student to understand complex energy systems in an international context. This is the backbone needed for solving the demanding challenges of future Energy systems.

2.2 Admission Requirements

The general legal admission requirements apply. The binding regulations for this curriculum can be found in:

- Study and examination regulations for the Bachelor study course Energy Systems and Renewable Energies (SPO ESYS)
- General Examination Regulations (APO) of Technische Hochschule Ingolstadt
- Matriculation Regulations of Technische Hochschule Ingolstadt.

In addition, the study program requires practical training or a preparatory internship. The duration for the required training at the Faculty of Mechanical Engineering is specified in accordance with §9 of the THI Matriculation Regulation and has to be completed either before the start of the study course or at the latest before the start of the 4th Semester (completion during the semester breaks).

2.3 Target Group

The course of study addresses:

- People interested in sustainable energy generation, energy supply and energy consulting and who intend to work in these fields
- People that want to contribute to counteracting climate change
- People with technical and scientific interests

2.4 Structure of the course

The standard period of study is seven semesters. The course breaks down into two phases. The first study phase comprises two theoretical semesters. The second study phase comprises four theoretical semesters and one internship semester, which is the fifth semester of study. From the sixth semester onward, the curriculum allows for individual customization and specialization by taking a total of three elective courses. These are described in a cross-program module handbook.

The following chart represents the course of study graphically:

1. Semester		
Engineering Mathematics 1	Computer Science in Engineering	Basics of Mechanical Design
Statics	Electrical Engineering	Energy Systems and Energy Economics
2. Semester		
Engineering Mathematics 2	Material Science	Mechanics of Materials
Thermodynamics 1	Energy Storage	Entrepreneurship and Sustainability
3. Semester		
Product Development and CAD	Measurement Engineering	Machine Elements
Thermodynamics 2	Fluid Mechanics	Thermal Energy Technology and Power Plants
4. Semester		
Project Design and Development	Control Engineering	Energy Distribution and CHP Plants
Building Technology and Smart Homes	Solar Energy Technologies	Cost and Investment Management
5. Semester		
Practical Seminar	Internship	Project and Quality Management
6. Semester		
Project	Elective	Elective
Solar Buildings and Energy Consulting	Energy Markets and Coupling Sectors	Smart Grids and Wind Energy
7. Semester		
Elective	Bachelor's Thesis and Seminar	
Energy from Biomass and Biogenic Residues	Mobility within the Energy System	

2.5 Advancement prerequisites

The following advancement prerequisites must be met (see SPO and APO for further details):

- Only those students who have acquired at least 42 ECTS credits from the modules of the first program phase are entitled to enter the second phase.
- Only those students who have achieved at least “sufficient” as a grade in all examinations and have acquired all relevant course-related credits of the first study section and have earned at least 20 ECTS credits from the compulsory modules of the second study phase are entitled to enter the internship as part of the practical semester.

2.6 Conception and Advisory Board

The course was developed, among other things, on the basis of discussions with company representatives, whose requirements were particularly taken into account. The alignment of the course with a focus on energy systems and renewable energies, including a high level of practical relevance, digitization and entrepreneurship resulting in a mix of subjects, arose not only because of the relevance of these topics for the economy but also for global development.

The training is intended to enable our Bachelor's graduates to be the driving force in companies when it comes to tackling future challenges.

3 Qualification profile

3.1 Concept

Upon completion of their studies, students will have a wide range of knowledge of power engineering technologies - with a high level of practical applicability - as well as good business contacts to the industry and the opportunity to gain international experience.

During their studies, students acquire deeper knowledge in a range of different systems such as building energy systems, off-grid systems, industry supply systems and energy systems in general. The related energy sources are solar power, biomass, wind power and geothermal energy. The course also covers other important fields of studies such as cogeneration technology, heat pumps and energy storage systems for controlling energy generation and consumption capacities. As part of these different modules, the mechanical and electrical engineering aspects that were introduced in the first semesters are specifically deepened.

In addition, new concepts for mobility (e-mobility, biomethane, power to gas - hydrogen and methane) are part of the curriculum. These new concepts lead to additional energy consumers that need to be efficiently integrated into the overall energy system. It is to be expected that in the future it will be possible to increasingly supply heat and cold sinks using heat pump systems, power to heat, solar heat and absorption chillers or renewable gases. In this context, students learn the skillfull use of these technologies and their flexibility potential for the integration of fluctuating renewable energies such as wind and sun.

In the “Energy Systems and Renewable Energies” course, one focus is on the integration and interaction within all areas from energy generation to consumption. Therefore, intelligent physical energy distribution (SmartGrids, heating networks, gas networks, digitization of communication) and virtual energy trading on the individual energy markets also play an important role.

At the same time, the students acquire the ability to carry out economic assessments of energy supply concepts in order to prepare investment decisions. These economic analyses together with the knowledge of entrepreneurship enables them to found and/or lead a company.

Students get an insight into various methods of digital engineering. They will use 3D-CAD (computer-aided design) software for mechanical design. They will learn to simulate thermodynamic and fluid dynamic processes, energy-technical plants and energy systems with commercial simulation tools, because the integration of different energy systems requires a high degree of digitization.

Therefore, graduates of the course are prepared for specialist and managerial tasks in various areas of energy systems and renewable energies. They take their social responsibility actively in their actions and help to shape a sustainable future and limiting climate change.

3.2 Study Objective

3.2.1 Specialist skills of the course

The following specialist skills are acquired:

- Knowledge of the basic contents of renewable energies and energy systems
- Knowledge of situational and relevant behavior in practice
- Selected skills in renewable energies and energy systems
- Capability to work scientifically as an engineer by applying basic engineering methods
- Selected skills in different methods of digitization
- Ability to apply and prove the basics learned during a semester-accompanying project as well as in the practical semester
- Opportunity to build on the academic education with a Master´s program
- Ability to plan and coordinate and carry out interdisciplinary projects on a budget, applying methods of modern quality management and recognizing potential for entrepreneurship

3.2.2 Interdisciplinary skills of the course

The following interdisciplinary skills are of particular importance for the study course:

Methodological Competences, Social- and Personal skills:

- Apply knowledge of basic principles of scientific work
- Being able to analyse problems and to recognize interdisciplinary correlations
- Apply engineering-scientific knowledge and methodologies in solving practical problems; evaluate solutions technically and economically and prepare decision memos
- Being able to solve tasks in small groups, while communicating and explaining professionally
- Familiarize yourself independently and in a team with defined topics and discuss them professionally
- Manage effectively areas of responsibility assigned to you and recognize connections with and impact on similar and subsequent areas of responsibility
- Develop methodological and social skills in areas such as teamwork, teambuilding, communication skills, project- and time management
- Communicate and present results
- Apply analytical and solution-oriented thinking skills to complex issues

- To shape their actions in the context of social processes in a critical, reflective and responsible manner with regard to a sustainable, climate-friendly future

3.2.3 Examination concept of the course

The examinations are based on the defined competences and the desired learning outcomes of a module, whose successful imparting will be checked.

The imparting of the basic knowledge is essential, especially in the basic subjects. In these fields it is important to check the extend to which the participants have mastered this broad knowledge by testing this as comprehensively as possible. Particularly suitable for this are written and oral examinations.

In the specializing subjects of the degree the focus is on imparting current specialist knowledge and its application in practice, as well as improving interdisciplinary skills. Especially suitable for this are examinations hold in terms of seminar- and term papers and project theses.

3.2.4 Application of the study course

When the course curriculum was drafted, the aspect of practical application was given a high priority.

The development of the course took place in alignment with practical relevance of the topics. There is an interdisciplinary transfer of skills including applicational reference. During the study program projects with a focus on practical experience and transfer take place. Bachelor thesis topics originate from professional practices or practical research.

3.2.5 Contribution of individual modules to the course objectives

In the compulsory modules, the course imparts mathematical, scientific and engineering expertise with subjects such as engineering mathematics, statics, mechanics of materials, basics of mechanical design, material science, computer science and digitization in engineering, thermodynamics, basics of electrical engineering and electronics, methods of product development and CAD, as well as basic business-management content with subjects such as cost and investment management and a project for the organization and establishment of sustainable businesses.

The students acquire expertise in the field of energy systems and renewable energies in energy-specific subjects such as "Energy Systems and Energy Economics", "Energy Storage", "Thermal Energy Technology and Power Plants", "Energy Distribution and CHP Plants", "Building Technology and Smart Homes", "Solar Energy Technologies" etc.

By working on projects (sustainability and entrepreneurship, project design and development, engineering project in the 6th semester) in small groups as well as in the internship and in the bachelor thesis, the students acquire both methodological, social and personal skills.

Methodological skills: On the basis of selected case studies and practical tasks the students expand their methodological skills. This enables the students, among other things, to present skillfully, to structure processes and to carry out projects successfully. They have the ability to acquire new knowledge independently. They will learn to plan, coordinate and carry out projects on a budget in an interdisciplinary manner and to apply methods of modern quality management.

Social skills: In small groups, the students not only strengthen their communication and teamwork skills, but also their ability to deal with conflicts. During regular attendance periods, as well as independent of time and location students will work collaboratively on complex topics and problems. They are used to giving and receiving constructive feedback. The students embed their specialist knowledge in an interdisciplinary context and also build up an extensive network from which they benefit beyond their studies.

Personal skills: The students are open to new ideas, pursue their goals persistently and with determination. Even under a heavy workload, they can set priorities, delegate tasks and make and enforce decisions courageously. The students question facts critically and reflect on their own actions with a view to their social responsibility.

3.3 Job profiles

The demand for qualified specialists in the field of energy systems in general and in the area of renewable energy forms in particular is enormous, as there is currently a lack of suitably qualified experts.

The graduates future fields of activity focus on the following sectors:

- Solar energy/ bio-energy /building energy/wind power
- Energy system technology, energy consulting and planning
- Graduates with a degree in energy technology are sought wherever energy is generated, stored and used – nowadays in all industries and companies
- All companies and local authorities as well as private and public institutions that pursue a sustainability strategy and/or want to become CO2-neutral

Graduates of the course are prepared for specialist and managerial tasks in the following areas:

- Sustainable energy generation and distribution
- Development, production and operation of energy technology plants and energy systems
- Planning of energy systems and energy consulting
- In Germany and worldwide, as multipliers, so to speak, who make a contribution to global activities against the climate crisis with their acquired knowledge and skills

Common career paths include recruitment by energy supply companies, jobs in the industry or with engineering service providers or planning offices, as well as the job profile of an independent consultant. In addition, it is not uncommon for graduates to find employment in medium-sized companies or official bodies

4 Dual Studies

A dual degree is not possible in this degree program.

5 Description of Modules

5.1 Compulsory subjects

Engineering Mathematics 1

Module abbreviation:	EMath1_ESYS	**SPO-No.:**	1
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	1
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only winter term

Responsible for module:	Horak, Jiri	
Lecturers:	Horak, Jiri	
Credit points / SWS:	5 ECTS / 5 SWS	
Workload:	Contact hours:	58 h
	Self-study:	67 h
	Total effort:	125 h
Subjects of the module:	1: Engineering Mathematics 1 (EMath1_ESYS)	
Lecture types:	SU/Ü - lecture with integrated exercises	
Examinations:	schrP120 - written exam, 120 minutes (EMath1_ESYS)	
Special features of the examination performance:	None	

Recommended prerequisites:

None

Objectives:

The students

- develop their ability to recognize which questions in engineering can be answered using mathematics and can ask such questions themselves.
- understand logical reasoning, recognize condition, consequence and rule, and can build a chain of reasoning in the context of engineering applications.
- recognize known types of tasks in known and new contexts, can solve these tasks using known procedures.
- understand the mathematical language used in engineering literature and can describe their own reasoning and solution approaches orally and in writing.
- are able to deal confidently with the mathematical methods presented.
- possess a basic knowledge of number systems, the notion of convergence, differential and integral calculus of functions of one variable, elementary differential equations, and their applications in engineering.

Content:

- Functions: basics, continuity, applications
- Differentiation in R: basics, rules, applications
- Integration in R: basics, methods of integration, applications
- Complex numbers: basics, rules, applications
- Ordinary differential equations: basics, solution methods, applications

Literature:
Compulsory: • STRANG, Gilbert, 2017. *Calculus*. Wellesley, MA: Wellesley-Cambridge Press. ISBN 978-0-9802327-5-2 • STEWART, James, 2021. *Calculus: early transcendentals*. Australia: Cengage Learning. ISBN 978-0-357-11351-6 Recommended: • STROUD, Kenneth Arthur and Dexter J. BOOTH, 2021. *Engineering mathematics*. New York; London; Oxford; New Delhi; Sydney: Bloomsbury Academic. ISBN 978-1-352-01027-5
Additional remarks:
None

Engineering Mathematics 2

Module abbreviation:	EMath_2_ESYS	**SPO-No.:**	2
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	2
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only summer term

Responsible for module:	Horak, Jiri	
Lecturers:	Kotonski, Julia	
Credit points / SWS:	5 ECTS / 5 SWS	
Workload:	Contact hours:	58 h
	Self-study:	67 h
	Total effort:	125 h
Subjects of the module:	2: Engineering Mathematics 2 (EMath_2_ESYS)	
Lecture types:	SU/Ü - lecture with integrated exercises	
Examinations:	schrP120 - written exam, 120 minutes (EMath_2_ESYS)	
Special features of the examination performance:	None	

Recommended prerequisites:

Engineering Mathematics 1

Objectives:

The students

- further develop their ability to recognize which questions in engineering can be answered using mathematics and can ask such questions themselves.
- understand logical reasoning, recognize condition, consequence and rule, and can build a chain of reasoning in the context of engineering applications.
- recognize known types of tasks in known and new contexts, can solve these tasks using known procedures.
- understand the mathematical language used in engineering literature and can describe their own reasoning and solution approaches orally and in writing.
- are able to deal confidently with the mathematical methods presented.
- possess a basic knowledge of series, matrices, differential and integral calculus of functions of several variables, and their applications in engineering.

Content:

- Series: basics, power and Taylor Series, applications
- Matrices: basics, determinants, eigenvalues and eigenvectors, applications
- Differentiation in R^n: basics, rules, applications
- Integration in R^n: basics, methods of integration, applications
- Introduction to vector calculus

Literature:
Compulsory: • STRANG, Gilbert, 2017. *Calculus*. Wellesley, MA: Wellesley-Cambridge Press. ISBN 978-0-9802327-5-2 • STEWART, James, 2021. *Calculus: early transcendentals*. Australia: Cengage Learning. ISBN 978-0-357-11351-6 Recommended: • STROUD, Kenneth Arthur and Dexter J. BOOTH, 2021. *Engineering mathematics*. New York; London; Oxford; New Delhi; Sydney: Bloomsbury Academic. ISBN 978-1-352-01027-5
Additional remarks:
None

Computer Science in Engineering

Module abbreviation:	CScEng_ESYS	**SPO-No.:**	3
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	1
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only winter term

Responsible for module:	Lange, Marlene
Lecturers:	Lange, Marlene (CScEng_ESYS) Lange, Marlene (CScEngAR_ESYS)
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 47 h Self-study: 78 h Total effort: 125 h
Subjects of the module:	3: Computer Science in Engineering (CScEng_ESYS) 3: Computer Science in Engineering (admission requirement) (CScEngAR_ESYS)
Lecture types:	SU/Ü/Pr - seminar based teaching / exercise course / laboratory
Examinations:	Computer Science in Engineering: schrP90 - written exam, 90 minutes (CScEng_ESYS) Computer Science in Engineering (admission requirement): prA -Practical work, 2-7 experiments with 2-5 pages of documentation each (CScEngAR_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

None

Objectives:

After attending the course, students

- understand the basic principles of data representation and processing with computers.
- have the ability to develop a solution to a given problem and to represent it as an algorithm so that it can be implemented into a programming language.
- have basic programming knowledge that enables the creation and execution of simple programs and the ability to define and implement the interfaces of a system.
- understand syntax and semantics of a programming language.
- achieve basic skills about the implementation of arbitrary real-world entities into a programming language.
- are able to create a structured model from a set of requirements that can be implemented in a programming language.
- have a practical understanding about hard and software in the field of computer science.
- can discuss within the field of computer science and engineering.

The goal of the admission requirement is that the students learn to practically apply the theory of the computer science course. They learn

- to develop and implement simple algorithms.
- to write, execute and debug a computer program.
- the basic syntax and semantics of a programming language.

Content:

- History of computers and programming languages
- Data representation within computers
- Introduction to algorithms
- Basic syntax and semantics of a programming language
- Variables and data types
- Control structures (loops, conditionals)
- Functions for code organization
- Working with basic data structures
- Writing and debugging code
- The principles of object-oriented programming (OOP)
- Creating and using classes and objects

The students have to solve a given number of tasks from the area of computer science. Depending on the level of task completion they are admitted to the final exam, or not.

Literature:

Compulsory:

None

Recommended:

- CORMEN, Thomas H. and others, 2009. *Introduction to algorithms*. Cambridge, Massachusetts; London, England: The MIT Press. ISBN 978-0-262-27083-0
- INDEN, Michael, 2022. *Python Challenges: 100 Proven Programming Tasks Designed to Prepare You for Anything* [online]. Berkeley, CA: Apress PDF e-Book. ISBN 978-1-4842-7398-2. Available via: https://doi.org/10.1007/978-1-4842-7398-2.
- PETZOLD, Charles, 2000. *CODE: the hidden language of computer hardware and software*. Redmond, Wash.: Microsoft Press. ISBN 0-7356-0505-X, 0-7356-1131-9
- MATTHES, Eric, 2023. *Python crash course: a hands-on, project-based introduction to programming*. San Francisco: No Starch Press. ISBN 978-1-7185-0270-3

Compulsory:

None

Recommended:

- See recommended literature for the Computer Science in Engineering course.

Additional remarks:

None

Material Science

Module abbreviation:	MatSc_ESYS	**SPO-No.:**	4
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	2
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only summer term

Responsible for module:	Oberhauser, Simon
Lecturers:	Oberhauser, Simon
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 47 h Self-study: 78 h Total effort: 125 h
Subjects of the module:	4: Material Science (MatSc_ESYS)
Lecture types:	SU/Ü/Pr - seminar based teaching/exercise course/laboratory
Examinations:	schrP90 - written exam, 90 minutes (MatSc_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

None

Objectives:

The students

- know the different types of chemical bonds and their occurrence in materials.
- are familiar with the most common metallic lattice structures and know the influence of these structural types on plastic formability.
- are able to denominate and sketch structural disorders and to explain the role of dislocations during plastic deformation.
- understand the context between different hardening mechanisms of metals and the kinds of disorder, responsible for the considered hardening effect.
- can explain the mechanisms of diffusion in solids, know the time and temperature dependence of diffusion processes and selected technical procedures, where diffusion plays an important role.
- are familiar with the basic types of phase diagrams in general and are able to interpret the phase diagram Iron Carbon in particular.
- understand how solidification processes are influenced by nucleation and crystal growth and therefore, how the microstructure and properties of cast parts can be controlled.
- know the fundamentals of the kinetics of solid-state reactions and understand the mechanism, course and result of martensitic transformation and precipitation reactions as well.
- know typical methods of material testing and characterization.

Content:

- Atomic structure and the nature of chemical bonding
- Structures of solids, especially metals

- Imperfections in real crystals
- Plastic deformation in ideal and real crystals, hardening effects by disorders
- Diffusion – mechanism, meaning and applications
- Phases and phase diagrams
- Kinetics of solidification
- Kinetics of solid-state reactions – martensitic transformation and precipitation reactions (hardening of metallic materials)
- Materials testing and material characterization

Literature:

Compulsory:

- ASKELAND, Donald R. and others, 2022. *The science and engineering of materials*. Boston, MA: Cengage. ISBN 978-0-357-44786-4, 978-0-357-44788-8

Recommended:

- CALLISTER, William D. and David G. RETHWISCH, 2020. *Materials science and engineering: an introduction*. 10. Edition. Hoboken, NJ: Wiley. ISBN 978-1-119-45391-8

Additional remarks:

None

Energy Systems and Energy Economics

Module abbreviation:	ESaEE_ESYS	**SPO-No.:**	5
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	1
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only winter term

Responsible for module:	Huber, Matthias
Lecturers:	Lwakatare, Bertha Phenias; Ngetuny, Joshua
Credit points / SWS:	5 ECTS / 5 SWS
Workload:	Contact hours: 58 h Self-study: 67 h Total effort: 125 h
Subjects of the module:	5: Energy Systems and Energy Economics (ESaEE_ESYS) 5: Energy Systems and Energy Economics (admission requirement) (ESaEEAR_ESYS)
Lecture types:	SU/Ü/PR - seminar based teaching/Exercise course/laboratory
Examinations:	Energy Systems and Energy Economics: schrP90 - written exam, 90 minutes (ESaEE_ESYS) Energy Systems and Energy Economics (admission requirement): prA - Practical work, 2-7 experiments with 2-5 pages of documentation each (ESaEEAR_ESYS)
Special features of the examination performance:	Aids in the exam: will be announced in the lecture

Recommended prerequisites:

none

Objectives:

The students

- understand today's energy supply (heat, electricity, and mobility) and are capable to evaluate it.
- are capable to judge the importance of the different forms of renewable energies in today's and future energy supply.
- are capable to evaluate fossil energy sources with their impact on the climate.
- understand the international and German energy and climate protection policy and the corresponding legislation.
- understand the economic aspects and market structures of the European and German energy supply.

The students

- actively contribute to the module´s contents.
- have an overview of current developments related to (renewable) energies and energy systems.
- gain experience in doing (desk) research of current developments related to (renewable) energies and energy systems.

- gain experience in presenting and discussing current developments related to (renewable) energies and energy systems.

Content:

Energy Systems Today and Tomorrow

- Basics of energy and energy-related terminology
- Energy consumption and supply worldwide / in Germany
- Energy efficiency
- Fossil fuels / nuclear energy
- Energy and climate
- Overview of renewable energies worldwide / in Germany

Energy Economics, Policies and Legislation

- Energy and climate protection policies worldwide / in Europe / in Germany
- Energy legislation in Europe / in Germany
- Renewable energies as an economic factor
- research of current developments related to (renewable) energies and energy systems
- presentation and discussion of current developments related to (renewable) energies and energy systems

Literature:

Compulsory:

None

Recommended:

- QUASCHNING, Volker, EPPEL, Herbert, 2020. *Renewable energy and climate change* [online]. Chichester, West Sussex, UK: Wiley PDF e-Book. ISBN 978-1-119-51490-9. Available via: https://doi.org/10.1002/9781119514909.
- QUASCHNING, Volker, 2016. *Understanding renewable energy systems* [online]. London and New York: Routledge PDF e-Book. ISBN 978-1-315-76943-1, 978-1-317-66942-5. Available via: https://doi.org/10.4324/9781315769431.
- HOSSAIN, Eklas, PETROVIC, Slobodan, 2021. *Renewable Energy Crash Course: A Concise Introduction* [online]. Cham: Springer International Publishing PDF e-Book. ISBN 978-3-030-70049-2. Available via: https://doi.org/10.1007/978-3-030-70049-2.
- BIGERNA, Simona, BOLLINO, Carlo Andrea, MICHELI, Silvia, 2015. *The sustainability of renewable energy in Europe* [online]. Cham: Springer International Publishing PDF e-Book. ISBN 978-3-319-12343-1, 978-3-319-12342-4. Available via: https://doi.org/10.1007/978-3-319-12343-1.

Compulsory:

None

Recommended:

None

Additional remarks:

None

Basics of Mechanical Design

Module abbreviation:	BMDesign_ESYS	**SPO-No.:**	6
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	1
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only winter term

Responsible for module:	Moll, Klaus-Uwe	
Lecturers:	Burger, Uli	
Credit points / SWS:	5 ECTS / 4 SWS	
Workload:	Contact hours:	47 h
	Self-study:	78 h
	Total effort:	125 h
Subjects of the module:	6: Basics of Mechanical Design (BMDesign_ESYS)	
Lecture types:	SU/Ü - lecture with integrated exercises	
Examinations:	schrP120 - written exam, 120 minutes (BMDesign_ESYS)	
Special features of the examination performance:	None	

Recommended prerequisites:

None

Objectives:

The students

- know which standards have to be taken into account for the creation of technical drawings.
- can use these standards to create complete and standardized graphic representations of constructions.
- can use the various projection methods.
- know what tolerances exist and can apply this knowledge correctly.
- can apply their knowledge of the representation of the representation of various machine elements in technical drawings.
- can develop new components and assemblies by linking their knowledge and design them for production.

Content:

- Contents of technical drawings
- Symbolic representations used
- Projection methods for the graphic representation of technical products
- Sectional representations, cutouts, views, details
- Dimensioning, dimensioning rules, edge symbols
- ISO tolerance system, surface information, shape and position tolerances, tolerance calculation
- Typical machine elements and standard parts and their graphic representation
- Design guidelines for various manufacturing processes
- Creation of freehand sketches

- Geometrical product specification

Literature:

Compulsory:

- GOMERINGER, Roland and others, 2018. *Mechanical and Metal Trades Handbook*. Haan-Gruiten: Verlag Europa-Lehrmittel, Nourney, Vollmer GmbH & Co. KG. ISBN 978-3-8085-1915-8, 3-8085-1915-0
- ISO, 2020. *ISO 128-1:2020: Technical product documentation (TPD) — General principles of representation — Part 1: Introduction and fundamental requirements*. Berlin: Beuth
- ISO, 2022. *ISO 128-2:2022: Technical product documentation (TPD) - General principles of representation - Part 2: Basic conventions for lines*. Berlin: Beuth
- ISO, 2022. *ISO 128-3:2022: Technical product documentation (TPD) - General principles of representation - Part 3: Views, sections and cuts*. Berlin: Beuth
- ISO, 2020. *ISO 128-100:2020: Technical product documentation - General principles of representation - Part 100: Index*. Berlin: Beuth
- DIN EN ISO, 2013. *ISO 286-1:2010 + Cor 1:2013: Geometrical product specifications (GPS) - ISO code system for tolerances on linear sizes - Part 1: Basis of tolerances, deviations and fits*. . Berlin: Beuth
- DIN EN ISO, 2013. *ISO 286-2:2010 + Cor 1:2013: Geometrical product specifications (GPS) - ISO code system for tolerances on linear sizes - Part 2: Tables of standard tolerance classes and limit deviations for holes and shafts*. Berlin: Beuth

Recommended:

None

Additional remarks:

None

Statics

Module abbreviation:	ST_ESYS	**SPO-No.:**	7
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	1
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only winter term

Responsible for module:	Feifel, Elke
Lecturers:	Feifel, Elke
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 47 h Self-study: 78 h Total effort: 125 h
Subjects of the module:	7: Statics (ST_ESYS)
Lecture types:	SU/Ü - lecture with integrated exercises
Examinations:	schrP90 - written exam, 90 minutes (ST_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

None

Objectives:

The students

- understand the principles and methods of the statics of rigid bodies and can apply these to mechanical engineering tasks.
- are able to convert real components and structures into simplified mechanical equivalent models.
- are able to analyze the loads acting on a mechanical system
- are able to calculate the bearing reactions and internal loads of statically determined structures under static loads.
- are able to work on three-dimensional problems.
- can calculate centers of gravity of lines, areas and volumes.
- understand the basic concept of friction and can solve problems relating to this.
- know the basic concepts of statics and can express themselves competently in the subject area.
- are able to confidently apply mathematical principles to calculations.
- have a capacity for abstraction and can solve tasks independently and in a team in a structured manner.

Content:

- Introduction to the basics of statics (bars, beams, plates, bearings and hinges, equilibrium conditions)
- Central and common force systems
- Analysis of mechanical structures, including trusses
- Forces, moments, resultants, support reactions
- Internal forces and moments

- Spatial mechanical systems
- Center of gravity
- Friction

Literature:

Compulsory:

None

Recommended:

- GROSS, Dietmar and others, 2013. *Engineering Mechanics Statics*. Dordrecht: Springer. ISBN 978-3-662-53853-1
- HIBBELER, Russel C., 2016. *Engineering Mechanics: Statics in SI Units*. 14. Edition. Hoboken: Pearson. ISBN 1-292-08923-7, 978-1-292-08923-2
- KESSEL, Siegfried and Dirk FRÖHLING, 2012. *Technische Mechanik - Engineering Mechanics Zweisprachiges Lehrbuch zu Grundlagen der Mechanik fester Körper - Bilingual Textbook on the Fundamentals of Solid Mechanics*. Wiesbaden: Springer. ISBN 978-3-8348-1719-8

Additional remarks:

None

Mechanics of Materials

Module abbreviation:	MechMat_ESYS	**SPO-No.:**	8
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	2
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only summer term

Responsible for module:	Dallner, Rudolf	
Lecturers:	Burger, Uli	
Credit points / SWS:	5 ECTS / 4 SWS	
Workload:	Contact hours:	47 h
	Self-study:	78 h
	Total effort:	125 h
Subjects of the module:	8: Mechanics of Materials (MechMat_ESYS)	
Lecture types:	SU/Ü - Seminar-based teaching with exercises	
Examinations:	schrP90 - written exam, 90 minutes (MechMat_ESYS)	
Special features of the examination performance:	None	

Recommended prerequisites:

successful participation in the module statics

Objectives:

The students

- are able to analyze and evaluate the stresses on machine parts and structures under static mechanical loads and to dimension these components.
- are able to calculate stresses and strains resp. deformations that occur in components as a result of loads such as tension/compression, bending, torsion or combined loading and evaluate them using strength hypotheses.
- can calculate deformations on beam-like components.
- understand the concept of stress tensor and can perform coordinate transformations and calculate principal stresses.
- can evaluate multiaxial stress states using equivalent stresses.
- are familiar with the basic concepts of elastostatics and are able to express themselves competently in the field of mechanics of material.
- are able to discuss and explain calculated results in a professional manner.
- are able to apply mathematical principles to calculations with confidence.
- have a capacity for abstraction and can solve tasks independently and in a team in a structured manner.

Content:

- Introduction to the basic concepts of mechanics of materials like stress and strain, Hooke's law and tension-compression as well as thermal expansion and thermal stresses
- Multiaxial stress states, transformation relations, stress tensor, principal stresses; Mohr's circle
- Linear elastic constitutive law for plane stress conditions and in the three-dimensional case

- Moments of inertia
- different types of loading, such as tension-compression, bending, torsion and the resulting stresses and deformations
- Deflections of beams under statically determinate and indeterminate conditions
- Combined loading and resulting stresses and deformations
- Equivalent stresses and stress evaluation, strength verification
- stress concentration problems
- Buckling of columns
- Extensive exercise examples of practical engineering applications according to the course of study

Literature:

Compulsory:

None

Recommended:

- HIBBELER, Russell C. and Jun Hwa LEE, 2024. *Statics and mechanics of materials*. Harlow: Pearson. ISBN 978-1-292-46020-8, 1-292-46020-2
- GROSS, Dietmar, GROSS, Dietmar, HAUGER, Werner, SCHRÖDER, Jörg, WALL, Wolfgang A., BONET, Javier, Band 2[2018. *Engineering mechanics* [online]. Berlin [u.a.]: Springer PDF e-Book. ISBN 978-3-662-56272-7. Available via: https://doi.org/10.1007/978-3-662-56272-7.
- GOMERINGER, Roland and others, 2018. *Mechanical and Metal Trades Handbook*. Haan-Gruiten: Verlag Europa-Lehrmittel, Nourney, Vollmer GmbH & Co. KG. ISBN 978-3-8085-1915-8, 3-8085-1915-0

Additional remarks:

None

Thermodynamics 1

Module abbreviation:	TD1_ESYS	**SPO-No.:**	9
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	2
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only summer term

Responsible for module:	Goldbrunner, Markus
Lecturers:	Goldbrunner, Markus
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 47 h Self-study: 78 h Total effort: 125 h
Subjects of the module:	9: Thermodynamics 1 (TD1_ESYS)
Lecture types:	SU/Ü/PR - seminar based teaching/Exercise course/laboratory
Examinations:	schrP90 - written exam, 90 minutes (TD1_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

None

Objectives:

The students

- know the properties of pure media (gases, liquids, homogenous mixtures) and the associated laws.
- are able to graphically represent and calculate changes of state of the model fluids "ideal gas" and "incompressible liquid" depending on the process control.
- are familiar with the laws of energy conversion (1st and 2nd law of thermodynamics).
- are able to describe the course of a thermodynamic process on the basis of the state variable entropy and to determine the energetic conversion quality of real state changes.
- can calculate and evaluate applied energetic single processes (compressor/turbine/heat exchanger).
- know the thermodynamic cycle processes of working and power machines and can thus make basic statements on the operating behaviour of these machines.
- are familiar with the basics of phase transformation in multiphase systems using water as an example.

Content:

- Chapter 1: Fundamentals of Thermodynamics
- Chapter 2: Exchange and conservation of energy (1st law of thermodynamics)
- Chapter 3: Exchange and generation of entropy (2nd law of thermodynamics)
- Chapter 4: Changes of state of model fluids

Literature:

Compulsory:

- WHITMAN, Alan M., 2023. *Thermodynamics: Basic Principles and Engineering Applications*. Cham: Springer International Publishing. ISBN 978-3-031-19538-9
- ÇENGEL, Yunus A., Michael A. BOLES and Mehmet KANOĞLU, 2024. *Thermodynamics: an engineering approach*. New York, NY: McGraw Hill. ISBN 978-1-266-15211-5, 1-266-15211-3
- PAUKEN, Michael, 2011. *Thermodynamics for dummies*. Hoboken, NJ: Wiley. ISBN 978-1-118-12098-9, 978-1-118-12100-9

Recommended:

- Will be announced in the lecture

Additional remarks:

None

Electrical Engineering

Module abbreviation:	ETE_ESYS	**SPO-No.:**	10
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	1
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only winter term

Responsible for module:	Navarro Gevers, Daniel	
Lecturers:	Navarro Gevers, Daniel; Ndong, Massa	
Credit points / SWS:	5 ECTS / 4 SWS	
Workload:	Contact hours:	47 h
	Self-study:	78 h
	Total effort:	125 h
Subjects of the module:	10: Electrical Engineering (ETE_ESYS)	
Lecture types:	SU/Ü - lecture with integrated exercises	
Examinations:	schrP90 - written exam, 90 minutes (ETE_ESYS)	
Special features of the examination performance:	None	

Recommended prerequisites:

None

Objectives:

The students

- know and use specialist terminology confidently.
- know the basic physical laws of electrical engineering and their connection.
- know the boundary conditions of particular laws of physics.
- are able to select the appropriate laws defining a given problem.
- are proficient in calculations with appropriate units.
- are proficient in methods calculating direct current and alternate current networks.
- know the electrical field quantities and are able to calculate them.
- know the magnetic field quantities and are able to calculate simple magnetic circuits.
- know simple circuits with a transistor.
- know basic circuits with an operational amplifier and are able to calculate those.
- know measuring instruments for electric quantities and know their possible uses.
- are able to familiarise themselves with subjects regarding electrical engineering self-reliant and within a team and are able to discuss these matters competently.

Content:

- Direct current circuits: voltage, current, Ohm´s law, energy, power, Kirchhoff´s laws, Thevenin equivalent
- Norton equivalent circuit, series connection, parallel connection, maximum power transfer, calculation of networks

- Electric field: electric field quantities, capacitance, energy in the electrostatic field, forces in the electrostatic field, switching operations
- Magnetic field: magnetic field quantities, coil inductance, magnetic circuit, magnetic flux law, magnetic energy of the coil, forces in the magnetic field, induction law, self-induction, switching operations
- Alternate current circuit: sinusoidal change of electric quantities, circuit analysis of alternate current networks using complex numbers, power
- Semiconductors: diode, transistor, operational amplifier, basics of electric circuits; digital circuits
- Measuring electric quantities

Literature:

Compulsory:

- HACKER, Viktor and Christof SUMEREDER, 2020. *Electrical engineering: fundamentals*. München; Wien: De Gruyter Oldenbourg. ISBN 9783110521023
- KORIES, Ralf and Heinz SCHMIDT-WALTER, 2003. *Electrical Engineering: A Pocket Reference*. Berlin, Heidelberg: Springer. ISBN 978-3-540-43965-3

Recommended:

- Further literature will be announced in the lecture.

Additional remarks:

None

Energy Storage

Module abbreviation:	EnergStor_ESYS	**SPO-No.:**	11
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	2
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only summer term

Responsible for module:	Schrag, Tobias
Lecturers:	Reum, Tobias; Schmitt, David
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 47 h Self-study: 78 h Total effort: 125 h
Subjects of the module:	11: Energy Storage (EnergStor_ESYS)
Lecture types:	SU/Ü/PR - seminar based teaching/Exercise course/laboratory
Examinations:	schrP90 - written exam, 90 minutes (EnergStor_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

None

Objectives:

The students

- can judge the need of storage according to the energy economic situation.
- can differentiate between base load and peal load storage.
- can evaluate different storages technologies according to a variety of criteria.
- can estimate the economic benefit of a storage system.
- can dimensionate storage systems.

Content:

- storage properties
- energy density
- storage cycles
- charging speed
- thermal energy storage
- hot tap water storges
- heating storage
- steam storage
- latent heat storage
- chemical storage
- dimensioning of storages

- electrical energy storages:
- battery basics
- charge control
- central vs decentral
- chemical storages
- gas storage hydrogen storage conversion efficiencies
- mechanical storages
- pumped hydro
- compressed air storage

Literature:

Compulsory:

None

Recommended:

- MATHEW, V. K., HOTTA, Tapano Kumar, ALI, Hafiz Muhammad, SUNDARAM, Senthilarasu, 2023. *Energy Storage Systems: Optimization and Applications* [online]. Singapore: Springer Nature Singapore PDF e-Book. ISBN 978-981-1945-02-1. Available via: https://doi.org/10.1007/978-981-19-4502-1.
- GUDE, Veera Gnaneswar, 2023. *Energy storage for multigeneration: desalination, power, cooling and heating applications*. London: Elsevier. ISBN 978-0-12-821921-8
- NAMRATA, Kumari, SAINI, R. P., KOTHARI, D. P., 2024. *Wind and Solar Energy Systems* [online]. Singapore: Springer Nature Singapore PDF e-Book. ISBN 978-981-9997-10-7. Available via: https://doi.org/10.1007/978-981-99-9710-7.
- BRUN, Klaus, Timothy ALLISON and Richard DENNIS, 2021. *Thermal, mechanical, and hybrid chemical energy storage systems*. London, United Kingdom; San Diego, CA, United States; Cambridge, MA, United States; Kidlington, Oxford, United Kingdom: Academic Press, an imprint of Elsevier. ISBN 978-0-12-819894-0

Additional remarks:

No remarks.

Entrepreneurship and Sustainability

Module abbreviation:	EntrSus_ESYS	**SPO-No.:**	12
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	2
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only summer term

Responsible for module:	Lange, Marlene
Lecturers:	Ramakrishna Babu Jai, Ganesh
Credit points / SWS:	5 ECTS / 5 SWS
Workload:	Contact hours: 58 h Self-study: 67 h Total effort: 125 h
Subjects of the module:	12: Entrepreneurship and Sustainability (EntrSus_ESYS)
Lecture types:	SU/Ü - lecture with integrated exercises
Examinations:	StA+Coll. (student research project with colloquium), written 8-15 pages, presentation 15-20 pages; oral exam 10-15 min. (EntrSus_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

None

Objectives:

The students

- have acquired basic knowledge in the areas of sustainability, sustainable development and sustainability management.
- have acquired an understanding of the main global challenges (such as climate change, resource scarcity) and understand the interactions between the dimensions of economy, ecology and social issues.
- understand what entrepreneurship means and which specific challenges are important for the start-ups.
- are familiar with the basic concepts and methods of innovation management.
- are able to transfer the principle of sustainability to their study contents.
- are able to link innovation and sustainability.
- are able to develop a business idea under consideration of sustainability criteria, to elaborate and present in a business plan.
- are able to apply agile innovation and product development methods and tools.
- are able to discuss and present results competently.
- understand the interaction of different disciplines.
- possess methodological and social skills in areas such as teamwork, communication skills, creative techniques, project management and time management.

Content:

Introduction: Understanding sustainability and sustainable development

- Fundamentals of sustainability and sustainable development
- Global challenges and risk posed by non-sustainability
- Opportunities of sustainable development
- Sustainability as a driver innovation
- Sustainable production and consumption

Theory of entrepreneurship

- What does "entrepreneurship" mean?
- Business models and the business model canvas
- Strategy, product development and marketing of start-ups
- Financing and selection of investors
- Contents of business plans

Theory of innovation management

- Definition and goals of innovation
- Types of innovations
- Sources/search fields for innovations
- Innovation strategy

Exercise Design Thinking: Sustainable Innovation and Business Model (development of a sustainable and feasible business idea in teamwork)

Literature:

Compulsory:

None

Recommended:

- SINEK, Simon, 2019. *Start with why: how great leaders inspire everyone to take action*. [London]: Penguin Business. ISBN 978-0-241-95822-3
- RIES, Eric, 2017. *The lean startup: how today's entrepreneurs use continuous innovation to create radically successful businesses*. New York: Currency. ISBN 978-1-5247-6240-7
- TIDD, Joseph and John R. BESSANT, 2021. *Managing innovation: integrating technological, market and organizational change*. Hoboken, NJ: Wiley. ISBN 978-1-119-71330-2

Additional remarks:

None

Machine Elements

Module abbreviation:	MachElem_ESYS	**SPO-No.:**	13
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	3
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only winter term

Responsible for module:	Moll, Klaus-Uwe
Lecturers:	Fuchs, Daniel
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 47 h Self-study: 78 h Total effort: 125 h
Subjects of the module:	13: Machine Elements (MachElem_ESYS)
Lecture types:	SU/Ü - lecture with integrated exercises
Examinations:	schrP90 - written exam, 90 minutes (MachElem_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

Statics, Basics of Mechanical Design, Mechanics of Materials, Material Science

Objectives:

At the end of the course, the students will be able to

- apply the terminology of the subject and discuss assignments with peers.
- to independently select and dimension the machine elements required for a design and to integrate it into an overall construction.
- apply the calculation and design methods for the treated machine elements on engineering level and to combine them with knowledge of statics, strength of materials, materials science and mechanical design.
- transfer the knowledge gained to other machine elements.

Content:

- Fastening screws (stress diagram, proof of strength statically and dynamically)
- Pins and bolts (load bearing capacity, shear stress)
- Springs (static and dynamic proof of strength for coil springs, disk springs, torsion springs)
- Axles and shafts (design and fatigue strength)
- Shaft-hub connections (positive and positive shaft-hub connections)
- Rolling bearings (service life calculation, design of storage and bearing point)
- Spur gears (gear law, design of spur gears and simple gears)
- Clutches (switchable and non-switchable clutches)
- seals and lubrication
- Other machine elements

Literature:

Compulsory:

- DIN, 2021. *6885-1: Drive type fastenings without taper action, parallel keys, keyways - Deep pattern*. Berlin: Beuth
- DIN, 2021. *6885-2: Drive type fastenings without taper action, parallel keys, keyways - Deep pattern for machine tools*. Berlin: Beuth
- DIN, 2021. *6885-3: Drive type fastenings without taper action, parallel keys, keyways - Low pattern - Part 3: Dimensions, tolerances, mass*. Berlin: Beuth
- DIN, 2012. *743-1: Calculation of load capacity of shafts and axles - Part 1: General*. Berlin: Beuth
- DIN, 2012. *743-2: Calculation of load capacity of shafts and axles - Part 2: Theoretical stress concentration factors and fatigue notch factors*. Berlin: Beuth
- DIN, 2012. *743-3: Calculation of load capacity of shafts and axles - Part 3: Strength of materials*. Berlin: Beuth
- DIN, 2012. *743-4: Calculation of load capacity of shafts and axles - Part 4: Fatigue limit, endurance limit - Equivalently damaging continuous stress*. Berlin: Beuth

Recommended:

- DECKER, Karl-Heinz, Frank RIEG and Karlheinz KABUS, 2018. *Maschinenelemente - Funktion, Gestaltung und Berechnung: mit 871 Bildern, 164 Berechnungsbeispielen und einem Tabellenband mit 334 Tabellen und Diagrammen*. 20. Edition. München: Hanser. ISBN 978-3-446-45029-5, 3-446-45029-7
- NISBETT, J. Keith and Richard G. BUDYNAS, 2024. *Shigley's Mechanical Engineering Design*. 12. Edition. New York: McGraw-Hill Education. ISBN 978-1266929892

Additional remarks:

Bonus system: In the course, students can work on and present tasks, which leads to bonus points according to their qualitative preparation and presentation, which are additionally credited to the examination performance. In relation to the points achievable in the examination, a maximum of 10 percent bonus points is possible. There is no entitlement to the implementation of the bonus system in the respective semester.

Thermal Energy Technology and Power Plants

Module abbreviation:	TETPP_ESYS	**SPO-No.:**	14
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	3
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only winter term

Responsible for module:	Goldbrunner, Markus
Lecturers:	Goldbrunner, Markus (TETPP_ESYS) Goldbrunner, Markus (TETPPAR_ESYS)
Credit points / SWS:	5 ECTS / 5 SWS
Workload:	Contact hours: 58 h Self-study: 67 h Total effort: 125 h
Subjects of the module:	14: Thermal Energy Technology and Power Plants (TETPP_ESYS) 14: Thermal Energy Technology and Power Plants (admission requirement) (TETPPAR_ESYS)
Lecture types:	SU/Ü/PR - seminar based teaching/exercise course/laboratory
Examinations:	Thermal Energy Technology and Power Plants: schrP90 - written exam, 90 minutes (TETPP_ESYS) Thermal Energy Technology and Power Plants (admission requirement): prA - Practical work, 2-7 experiments with 2-5 pages of documentation each (TETPPAR_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

None

Objectives:

The students

- have an overview of thermal energy systems and the most important processes used here.
- have an overview of the most important types of heat generation and can carry out simple combustion calculations.
- are familiar with the operating principle, the theoretical principles and the structure of fluid flow machines and can calculate them.
- are familiar with heat-power processes and their components and can calculate them.
- are familiar with the operating principle, theoretical principles and design of heat engines, such as steam turbines, gas turbines and internal combustion engines.
- have an overview of the different fuel cell concepts with fuels such as natural gas and hydrogen and know their construction.
- know the operating principle, theoretical principles and design of refrigeration machines and heat pumps.
- can apply what they have learned to the conceptual design and layout of heat engines and processes.

Students are expected to apply the theoretical content they have learned to practical experiments and a simulation using a commercial software tool.

Content:

Fundamentals of thermal energy systems

- Power and working machines
- Changes of state and cyclic processes
- Optimisation of cyclic processes

Heat generation

- Combustion
- Solar, geothermal and nuclear heat generation

Fundamentals of the fluid machine

- Structure
- Classification
- Energy conversion

Steam power process

- Basics
- Steam generator and firing
- Flue gas cleaning
- Cooling
- Steam turbine
- Further components

other processes with external heat generation

- ORC
- Kalina
- Stirling
- Steam engine

Internal combustion engine

- Basics and operation
- Components
- Gas engines

Gas turbine

- Fundamentals and mode of operation
- Components
- Micro gas turbines

Fuel cell

- How it works
- Fuel cell types, basics and fuels such as hydrogen
- Construction, components and service life

Working machines

- Basics
- Refrigerating machine
- Heat pump
- Simulation of a steam power plant with the software "Ebsilon".
- Execution of an experiment on the laboratory steam power plant with recording of measured process values and evaluation of the measured values.

- Execution of an experiment on the laboratory combustion engine with recording of measured process values and evaluation of the measured values.

Literature:

Compulsory:

- SARKAR, Dipak K., 2015. *Thermal power plant: design and operation*. Amsterdam: Elsevier. ISBN 978-0-12-801755-5, 0-12-801755-4
- GAMBINI, Marco and Michela VELLINI, 2021. *Turbomachinery: Fundamentals, Selection and Preliminary Design*. Cham: Springer. ISBN 978-3-030-51298-9
- STONE, Richard, 1999. *Introduction to Internal Combustion Engines* [online]. London: Macmillan Education UK PDF e-Book. ISBN 978-1-349-14916-2. Available via: https://doi.org/10.1007/978-1-349-14916-2.

Recommended:

- Will be announced in the lecture.

Compulsory:

None

Recommended:

None

Additional remarks:

None

Product Development and CAD

Module abbreviation:	ProdDevCAD_ESYS	**SPO-No.:**	15
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	3
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only winter term

Responsible for module:	Moll, Klaus-Uwe
Lecturers:	Moll, Klaus-Uwe (ProdDevCAD_ESYS) Beil, Florian, (ProdDevCADAR_ESYS)
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 47 h Self-study: 78 h Total effort: 125 h
Subjects of the module:	15: Product Development and CAD (ProdDevCAD_ESYS) 15 Product Development and CAD (admission requirement) (ProdDevCADAR_ESYS
Lecture types:	SU/Ü/PR - seminar based teaching/exercise course/laboratory
Examinations:	Product Development and CAD: schrP90 - written exam, 90 minutes (ProdDevCAD_ESYS) Product Development and CAD (admission requirement): prA -practical work, 2-7 experiments with 2-5 pages of documentation each
Special features of the examination performance:	Working with the 3D CAD system CATIA • part design: design of cubic and cylindric parts, based on proper sketches, adaptive and parametric design of parts, mainly based on geometrical dependencies • drafting of parts: views and sections views of parts, cutouts, detail views, dimensioning, introduction of ISO-tolerances, surface roughnesses, geometrical tolerances • assembly design: generation of sub-assemblies based on contraints, check of proper assembly design by clash checks and manipulations and re-assemblies, generation of full assembly based on sub-assemblies and further (given) parts, development of additional parts in the full assembly • drafting of assemblies: views and section views of assemblies, proper representation of different parts in assembly drawings Successful completion is a prerequisite for admission to the examination in the subject Methods of product development and CAD. The successful completion consists in the fact that CAD constructions are created, checked by the lecturer and certificates are awarded if they are free of errors. If all certificates are obtained, the prerequisite for participation in the examination is fulfilled. The extent of this will be announced in the course.
Recommended prerequisites:	
None	

Objectives:

The students

- know the procedure of the systematic and method-based approach in product development.
- understand the relationships between development and construction and other specialist areas of a developing and manufacturing company.
- independently develop sophisticated products by applying the methods taught and using adequate work techniques.
- understand the communication required for product development in a company.
- apply the knowledge to be a functional and social member of a project team.
- independently develop components and assemblies with the 3D CAD system CATIA (creation of models, creation of assemblies, derivation of standard-compliant drawings).

Students

- know approaches and procedures for the development of a 3d-model.
- develop on their own 3d-designs of parts and assemblies with the 3d-CAD-system CATIA.
- generate 2D-drawings of these parts and assemblies using CAD-system CATIA incl. complete dimensioning and tolerances.
- are able to make a quality check of their design work on their own.

know procedures about generation f a specification tree and data management in CAD-system CATIA.

Content:

- basic phases of the product development process
- Requirement specification, functional specification, specification
- abstraction
- Functional structures
- Search for solutions and creativity techniques to find solutions
- Systematic preparation of solution approaches (morphology) and variation and combination techniques
- Evaluation of concepts and concept selection
- Creation of technical drafts, draft construction
- Basic design rules, guidelines and principles
- Basic construction elements
- Semester exercise to implement the material learned
- Sketcher: Generation, setup and parameterization of sketches as a starting point for the generation of 3D-parts in CATIA
- Part Design: Generation of 3D-parts, cubic and rotational
- Drafting (part 1): setup of worksheet, generation of drawing of parts with different views, cutouts, detail views, dimensioning, introduction of ISO-tolerances, surface roughnesses, geometrical tolerances
- assembly design: generation of sub-assemblies based on contraints, check of proper assembly design by clash checks and manipulations and re-assemblies, generation of full assembly based on sub-assemblies and further (given) parts, development of additional parts in the full assembly
- drafting of assemblies: views and section views of assemblies, proper representation of different parts in assembly drawings

Literature:

Compulsory:

- PAHL, G., W. BEITZ and J. FELDHUSEN, 2014. *Engineering Design: A systematic approach*. ISBN 978-1447160250
- LIST, Ronald, 2017. *CATIA V5 – Grundkurs für Maschinenbauer: Bauteil- und Baugruppenkonstruktion, Zeichnungsableitung* [online]. Wiesbaden: Springer Vieweg PDF e-Book. ISBN 978-3-658-17333-3. Available via: https://doi.org/10.1007/978-3-658-17333-3.

- PLANTENBERG, Kirstie, 2009. *An introduction to CATIA V5: release 19; (a hands-on tutorial approach)*. [Mission, Kan.]: Schroff Development Corp. ISBN 978-1-58503-534-2
- VDI, 2019. *2221: Design of technical products and systems - Model of product design*. Berlin: Beuth
- VDI, 2019. *2221 Blatt 2: Design of technical products and systems - Configuration of individual product design processes*. Berlin: Beuth

Recommended:

None

Compulsory:

- LIST, Ronald, 2017. *CATIA V5 – Grundkurs für Maschinenbauer: Bauteil- und Baugruppenkonstruktion, Zeichnungsableitung* [online]. Wiesbaden: Springer Vieweg PDF e-Book. ISBN 978-3-658-17333-3. Available via: https://doi.org/10.1007/978-3-658-17333-3.

Recommended:

None

Additional remarks:

Bonus system: In the course, students can work on and present tasks, which leads to bonus points according to their qualitative preparation and presentation, which are additionally credited to the examination performance. In relation to the points achievable in the examination, a maximum of 10 per cent bonus points are possible. There is no entitlement to the implementation of the bonus system in the respective semester.

Project Design and Development

Module abbreviation:	ProjDesDev_ESYS	**SPO-No.:**	16
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	4
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	winter and summer term

Responsible for module:	Binder, Thomas
Lecturers:	Kessler, Phillip; NeuerProf_01, John; Schlingensiepen, Jörn; Suchandt, Thomas
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 47 h Self-study: 78 h Total effort: 125 h
Subjects of the module:	16: Project Design and Development (ProjDesDev_ESYS)
Lecture types:	S/PR - seminar/laboratory
Examinations:	Proj - Project report (5-25 pages) and presentation (15 min.) (ProjDesDev_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

None

Objectives:

The students

- are able to work independently and successfully on a complex development and design task in a team over the course of one semester.
- acquire the skills and methods to apply basic engineering and technical knowledge to concrete engineering tasks, e.g. development, design and construction of vehicle parts and components.
- are able to independently familiarise themselves with a topic of a constructive nature that is new to them and systematically work on it using engineering methods.
- are capable of executing designs according to functional, technical-economic, manufacturing and environmental criteria.
- are able to competently discuss, present and document achieved project results in accordance with technical standards.
- understand the interaction of different disciplines in the design process.
- possess methodological and social competence in areas such as teamwork, communication skills, creative techniques, project management and time management.

After attending the course, the dual students are able to deal with the offered topic in greater detail and solve more complex tasks due to the broader experience gained through the practical phases and the application of the theoretical content in the companies.

Content:

- Working on a practical, constructive study project in a team; the tasks vary from semester to semester; usually several topics are offered, from which one is selected.
- Getting to know and applying methodical construction

Due to the practical experience already gained in the dual company, dual students have a better starting position for developing the course content. The practical experience is actively integrated in the internship, dual students can contribute their knowledge and already acquired competences.

Adapted courses for dual students:

- Optional: Crediting of project tasks from company practice with proof through appropriate documentation in accordance with the planned examination performance.
- Increased complexity of the project task in existing courses
- Consideration of the in-depth applicability of the contents

Literature:

Compulsory:

- ULRICH, Karl T., Steven D. EPPINGER and Maria C. YANG, 2020. *Product design and development*. New York, NY: McGraw-Hill. ISBN 978-1-260-56954-4
- PROJECT MANAGEMENT INSTITUTE, 2021. *The Project Management and A Guide to the Project Management Body of Knowledge (PMBOK Guide)*. ISBN 978-1-62825-664-2
- Further topic-specific literature will be specified at the beginning of the course

Recommended:

None

Additional remarks:

The project work is a group work in which several students work on a common task in a team and present the results orally and in writing. Each student has to contribute individually to the joint task and deliver an oral presentation of 15 minutes. The written part has a length of approx. 5-25 pages per student.

Energy Distribution and CHP Plants

Module abbreviation:	EnergDistCHPP_ESYS	**SPO-No.:**	17
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	4
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only summer term

Responsible for module:	Huber, Matthias
Lecturers:	Denter, Niklas; Sander, Peter; Selleneit, Volker
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 47 h Self-study: 78 h Total effort: 125 h
Subjects of the module:	17: Energy Distribution and CHP Plants (EnergDistCHPP_ESYS)
Lecture types:	SU/Ü/PR - seminar based teaching/Exercise course/laboratory
Examinations:	schrP90 - written exam, 90 minutes (EnergDistCHPP_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

Combination with other lectures/topics

Builds on and deepens other lectures:
Energy economics and renewable energies

Objectives:

The students

- gain extensive knowledge of CHP technology, its operation and economic influences, taking into account the relevant fuels.
- are able to evaluate CHP plants as energy centers at different locations. They know their economic influencing variables, as well as the allocation methods to evaluate the CO2 reduction.
- learn about CHP technology as a plannable and flexible energy supply technology.
- have an overview of the possibilities to distribute heat and cold.
- they deal in depth with the topic of heat networks and are able to design them.
- gain knowledge about hydrogen as an energy carrier.
- know the interactions between the different heat sources and the heat network (temperature levels) and their effect on operating costs as well as energy losses.
- get an introduction into sector coupling energy system planning.

Content:

CHP (electricity and heat supply by means of gas-fired CHP):

- CHP technology

- Efficiencies, influencing factors, utilization rates, efficiency
- CO2 reduction, allocation methods for CO2 reduction evaluation
- Cost structure: heat supply costs, electricity supply costs
- Operating modes: historical, current and future
- Efficient integration of CHP (heat and power) into the energy system
- Permitting aspects (exhaust emissions, installation site, noise)
- Legal framework for CHP operation
- Design of future sites
- "Green" hydrogen as an energy carrier

Heat distribution (deeper insight into energy distribution by means of heat network):

- Heat sinks (demand profiles)
- Losses
- Flow/return temperature
- Heat storage, hydraulic separator
- Transfer systems
- Influencing variables
- Cold networks and heat pumps
- Integration of solar thermal energy into heating networks
- Large solar thermal fields
- Heat storage especially in connection with solar thermal energy
- Economic efficiency of solar thermal energy

Basics of gas networks (energy distribution by means of gas network):

- pipeline-based energy transport (transport capacity, capacity price, working prices)
- Basics and basic terms (gaseous transport)
- gas quality (natural gas, hydrogen, biomethane, e-gas)
- Structure and components of a gas pipeline
- Transport network in Europe / Germany
- DVGW regulations

Basics of electricity grids (regulatory and energy industry):

- Historical development
- Electricity distribution structures
- Technical overview (voltage levels, tasks, responsibilities, structures)
- European / German power grid
- Current developments (network development plan, etc.)

Literature:

Compulsory:

- SCHMIDT, Dietrich, 2023. *Guidebook for the digitalisation of district heating: transforming heat networks for a sustainable future: final report; Annex TS4, Digitalisation of district heating, optimised operation and maintenance of district heating and cooling systems via Digital Process Management*. Frankfurt am Main: AGFW-Project Company. ISBN 3-89999-096-X
- BREEZE, Paul, 2018. *Combined heat and power*. London; San Diego; Cambridge, MA; Kidlington, Oxford: Elsevier. ISBN 978-0-12-812908-1, 0128129085
- FREDERIKSEN, Svend and Sven WERNER, 2013. *District heating and cooling*. Lund: Studentlitteratur. ISBN 978-91-44-08530-2
- HORLOCK, *Cogeneration-combined heat and power (CHP): thermodynamics and economics*.
- HORLACHER, HELBIG and AIGNER, *Hydro- und Gasdynamik*.

- KERSTING, William H., 2002. *Distribution system modeling and analysis*. Boca Raton [u.a.]: CRC Press. ISBN 0-8493-0812-7
- GÖNEN, Turan, Chee-Wooi TEN and Ali MEHRIZI-SANI, 2024. *Electric power distribution engineering*. Boca Raton: CRC Press. ISBN 978-0-367-65495-5, 978-0-367-65499-3

Recommended:

- Further literature will be announced in lecture.

Additional remarks:

No remarks.

Smart Grids and Wind Energy

Module abbreviation:	SmGrWiEnerg_ESYS	**SPO-No.:**	18
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	6
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only summer term

Responsible for module:	Navarro Gevers, Daniel
Lecturers:	Navarro Gevers, Daniel; Scherer Farina, Anneliese
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 47 h Self-study: 78 h Total effort: 125 h
Subjects of the module:	18: Smart Grids and Wind Energy (SmGrWiEnerg_ESYS)
Lecture types:	SU/Ü/PR - seminar based teaching/Exercise course/laboratory
Examinations:	schrP90 - written exam, 90 minutes (SmGrWiEnerg_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

None

Objectives:

The students

- know the function of the most important network operating resources in the power grid. The functionality and communicative networking and control of power generators, consumers and storage systems are known and can be described.
- can differentiate between energy transmission networks and distribution networks and distinguish between their main tasks.
- learn which intelligent solutions are available or possible in the future for the grid integration of renewable energy sources into the power grid.
- can reproduce control structures such as load control, frequency control or voltage control.
- will be able to analyze and understand wind data. They can assume a distribution and perform probability calculations.
- can calculate the annual energy yield of a wind farm at a given location.
- will be able to prepare a technical specification for a wind turbine.
- will be able to select specific wind turbines on the market that meet the project specifications.

Content:

1. Network resources, generators and consumers:

- Generators/consumers
- Transformers
- Generators

- Storage facilities
- Smart metering, intelligent meters
- Converter technology
- Grid topologies

2. Grid stability strategies

- Grid integration, grid stability
- Forecasting methods
- Load control/load shifting

3. Energy systems of the future

- Smart grids

4. Wind Power

- Technical basics of a wind turbine
- Evaluating wind data
- Energy calculation
- Selection of a wind turbine
- Use of artificial intelligence in the maintenance strategy
- Rudiments of power electronics

Literature:

Compulsory:

None

Recommended:

- HAU, Erich, 2013. *Wind turbines: fundamentals, technologies, application, economics; 41 tables* [online]. Berlin [u.a.]: Springer PDF e-Book. ISBN 978-3-642-27151-9. Available via: https://doi.org/10.1007/978-3-642-27151-9.
- REKIOUA, Djamila. *Wind Power Electric Systems: Modeling, Simulation, Control and Power Management Control*. ISBN 978-3-031-52883-5
- SGUAREZI, Alfeu and others, 2024. *Smart grids - renewable energy, power electronics, signal processing and communication systems applications*. Cham, Switzerland: Springer. ISBN 978-3-031-37908-6, 978-3-031-37911-6

Additional remarks:

The lecture is held in attendance and online.

Solar Energy Technologies

Module abbreviation:	SolET_ESYS	**SPO-No.:**	19
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	4
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only summer term

Responsible for module:	Zörner, Wilfried
Lecturers:	Trinkl, Christoph; Weitz, Klaus Peter (SolET_ESYS) Trinkl, Christoph; Weitz, Klaus Peter (SolETAR_ESYS)
Credit points / SWS:	5 ECTS / 5 SWS
Workload:	Contact hours: 58 h Self-study: 67 h Total effort: 125 h
Subjects of the module:	19: Solar Energy Technologies (SolET_ESYS) 19: Solar Energy Technologies (admission requirement) (SolETAR_ESYS)
Lecture types:	SU/Ü/PR - seminar based teaching/Exercise course/laboratory
Examinations:	Solar Energy Technologies: schrP90 - written exam, 90 minutes (SolET_ESYS) Solar Energy Technologies (admission requirement): prA - Practical work, 2-7 experiments with 2-5 pages of documentation each (SolETAR_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

None

Objectives:

The students

- have a theoretical and practical understanding of the direct use of the sun as an energy source.
- have an overview of the status and framework conditions of solar heat utilisation as well as the potentials, possible applications and challenges.
- understand the generation of solar heat in small and large solar systems for different applications.
- are familiar with the components and system configurations of solar useful heat generation.
- understand design methods and tools and are able to use them in project planning.
- are able to simulate a solar thermal system and carry out an ecological and economic evaluation.
- know and understand the development of photovoltaics in recent years, they can interpret and classify the current status.
- understand the different components, the physical principles, the manufacturing processes and the functioning of solar cells and photovoltaic systems.
- can design and plan photovoltaic systems.
- understand the integration of photovoltaic systems into the building technology and can simulate self-consumption and self-production of electricity.

The students

- understand functionalities and energy flows in solar thermal systems.
- can evaluate the efficiency and practical behaviour of solar thermal systems.
- understand solar collector efficiency testing procedures.
- can evaluate collector efficiency under different operational conditions.
- have a thorough understanding of functionalities, characteristics, potentials and limitations of different testing facilities for solar collectors and systems.

Content:

- Basics of solar energy:
  - Solar energy resources, solar irradiation on earth, calculation of the position of the sun, solar irradiation on inclined planes, shading, measurement methods.
- Solar thermal energy in the energy mix of the future
  - Use of solar thermal energy globally, at European and national level, perspectives of solar thermal energy in the energy mix
- Solar thermal systems (incl. laboratory course)
  - System variants and components for solar thermal domestic hot water, space heating, thermosiphon and solar air systems, design and operational strategies of solar thermal systems, solar yield and costs, area of application, design, and special features of large solar systems.
- Solar thermal collectors (incl. laboratory course)
  - Conversion of solar radiation into heat, efficiency of thermal collectors, collector types, design, installation, and operation of collector arrays.
- Modelling and simulation of solar thermal systems (incl. simulation workshop)
  - Opportunities and limitations of solar system simulation, areas of application and available software, modelling, parameter definition, simulation and results interpretation by means of application examples in the Polysun software suite.
- Photovoltaic
  - Development of photovoltaics in Germany and the world, the German Renewable Energy Act and the photovoltaic market.
  - Function and manufacturing process of a solar cell.
  - Functionality and tasks of an inverter.
  - Planning of a photovoltaic system (roof layout, inverter design, statics, ...).
  - Installation, cleaning and maintenance of photovoltaic systems.
  - Self-consumption of electricity (consumption profile, supply profile, consumption adoption, battery storage).
  - Other forms of photovoltaic systems (tracking systems, off-grid systems, ground-mounted systems)
- Experimental analysis of functionalities and energetic performance of solar thermal systems: System components and their functionalities, energy flows, storage tank behaviour, collector efficiency
- Solar collector testing according to EN ISO 9806: Solar irradiance and collector optics, testing procedures and facilities, efficiency testing and evaluation

Literature:

Compulsory:

None

Recommended:

- QUASCHNING, Volker, 2016. *Understanding renewable energy systems* [online]. London and New York: Routledge PDF e-Book. ISBN 978-1-315-76943-1, 978-1-317-66942-5. Available via: https://doi.org/10.4324/9781315769431.
- EICKER, Ursula, ©2003. *Solar technologies for buildings* [online]. Chichester: Wiley PDF e-Book. ISBN 978-1-60119-550-0, 1-60119-550-8. Available via: https://onlinelibrary.wiley.com/doi/book/10.1002/0470868341.

- DUFFIE, John A., BECKMAN, William A., 2013. *Solar engineering of thermal processes* [online]. Hoboken, NJ: Wiley PDF e-Book. ISBN 978-1-118-67160-3, 978-0-470-87366-3. Available via: https://onlinelibrary.wiley.com/doi/book/10.1002/9781118671603.
- TIWARI, G. N., TIWARI, Arvind, SHYAM, 2016. *Handbook of Solar Energy: Theory, Analysis and Applications* [online]. Singapore: Springer Singapore PDF e-Book. ISBN 978-981-10-0807-8. Available via: https://doi.org/10.1007/978-981-10-0807-8.
- ALEXOPOULOS, Spiros, KALOGIROU, Soteris A., 2022. *Solar Thermal Energy* [online]. New York, NY: Springer US PDF e-Book. ISBN 978-1-07-161422-8. Available via: https://doi.org/10.1007/978-1-0716-1422-8.

Compulsory:

None

Recommended:

None

Additional remarks:

None

Thermodynamics 2

Module abbreviation:	ThermDyn2_ESYS	**SPO-No.:**	20
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	3
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only winter term

Responsible for module:	Bschorer, Sabine
Lecturers:	Bschorer, Sabine
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 47 h Self-study: 78 h Total effort: 125 h
Subjects of the module:	20: Thermodynamics 2 (ThermDyn2_ESYS)
Lecture types:	SU/Ü/PR - seminar based teaching/Exercise course/laboratory
Examinations:	schrP90 - written exam, 90 minutes (ThermDyn2_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

None

Objectives:

After attending the module courses, participants will be able to

- derive the differential equations of heat conduction on a volume element and solve these with given local/temporal boundary conditions.
- characterize fluids using similarity parameters in order to calculate the heat transfer coefficient by means of appropriate Nusselt correlations.
- plot temperature profiles in heat exchangers depending on the operating conditions and use characteristic diagrams to design heat exchangers or to evaluate feasible exit temperatures.
- apply the principles of electro-magnetic heat radiation and of black and grey body radiation formula in order to approximate the heat transport of high temperature solids.
- apply heat transfer mechanisms in the practical laboratory course.

Content:

Heat exchange by heat conduction

- Fourier differential equation (heat conduction equation)
- One-dimensional steady heat conduction
- One-dimensional transient heat conduction

Heat transfer by convection

- Basics of thermo fluid dynamics
- Forced convection
- Natural convection

- Heat exchangers

Heat transfer by radiation

- Basic concepts of radiation
- Solid body radiation

Practical laboratory course

- Test preparation
- Test realisation
- Test evaluation

Literature:

Compulsory:

None

Recommended:

- INCROPERA, Frank P. and others, 2017. *Incropera's principles of heat and mass transfer*. Hoboken, NJ: Wiley. ISBN 978-1-119-38291-1, 1-119-38291-2
- KARWA, Rajendra, 2020. *Heat and Mass Transfer* [online]. Singapore: Springer Singapore PDF e-Book. ISBN 978-981-153-988-6. Available via: https://doi.org/10.1007/978-981-15-3988-6.
- VENKATESHAN, S.P., 2021. *Heat Transfer* [online]. Cham: Springer International Publishing PDF e-Book. ISBN 978-3-030-58338-5. Available via: https://doi.org/10.1007/978-3-030-58338-5.
- NELLIS, G. F. and S. A. KLEIN, 2021. *Introduction to engineering heat transfer*. Cambridge: Cambridge University Press. ISBN 978-1-107-17953-0

Additional remarks:

None

Fluid Mechanics

Module abbreviation:	FluMech_ESYS	**SPO-No.:**	21
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	3
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only winter term

Responsible for module:	Bschorer, Sabine
Lecturers:	Bschorer, Sabine (FluMech_ESYS) Bschorer, Sabine (FluMechAR_ESYS)
Credit points / SWS:	5 ECTS / 5 SWS
Workload:	Contact hours: 58 h Self-study: 67 h Total effort: 125 h
Subjects of the module:	21: Fluid Mechanics (FluMech_ESYS) 21: Fluid Mechanics (admission requirement) (FluMechAR_ESYS)
Lecture types:	SU/Ü/PR - seminar based teaching/Exercise course/laboratory
Examinations:	Fluid Mechanics: schrP90 - written exam, 90 minutes (FluMech_ESYS) Fluid Mechanics (admission requirement): prA - Practical work, 2-7 experiments with 2-5 pages of documentation each (FluMechAR_ESYS)
Special features of the examination performance:	LN = admission requirement for the exam (Leistungsnachweis) Within a practical course a total of 5 experiments are carried out in the laboratory. The students prepare an experimental protocol for each experiment. In addition, an exercise task must be presented in class. Proof of performance (grade 'passed') is achieved if the experiments have been carried out successfully and the presentation of the task has been carried out satisfactorily. Successful participation in 5 laboratory sessions and presentation of one exercise as a group

Recommended prerequisites:

None

Objectives:

After attending the module courses, participants will be able to

- understand and use the technical terms.
- calculate analytically and evaluate either incompressible and compressible flow through pipes and around bodies.
- estimate analytically pressure losses and energy consumption of fluid mechanics problems.
- describe roughly the flow simulation (Computational Fluid Dynamics), in other words the digitalization in the field of fluid mechanics.
- use flow measuring devices independently and to evaluate experiments.

The students deepen the lecture material during laboratory hours (learning by doing), to use flow measuring devices independently and to evaluate experiments.

Content:

- Introduction and basic concepts
- Properties of fluids (density, viscosity)
- Hydrostatics and aerostatics
- Conservation equations (continuity, Bernoulli, lateral pressure, momentum conservation and Navier-Stokes-equations)
- Dimensionless quantities: Re, Ma-number
- Incompressible flow through bodies: viscous pipe flow, laminar vs. turbulent, pressure loss, pipe friction, non-circular sections, losses in pipeline elements (manifolds, nozzle)
- Incompressible flow around bodies: laminar vs. turbulent boundary layer, pressure and frictional resistance, aerodynamic forces on vehicles and aerofoils, Magnus effect
- Compressible flow: fundamental equations, pipe flow, process of outflow, de Laval nozzle
- Overview of flow simulation (approach, base equations, examples of use)
- Laboratory work about the topics as wind tunnel, flow around and through bodies
- Laboratory work about the topics: Wind tunnel, external and internal flow, wind turbine, supersonic flow
- Calculation of an exercise and presenting it to the group

Literature:

Compulosry:

None

Recommended:

- ÇENGEL, Yunus A., John M. CIMBALA and Mehmet KANOĞLU, 2020. *Fluid mechanics: fundamentals and applications*. [Singapore]: McGraw-Hill. ISBN 978-981-315-788-0, 981-315-788-7
- JANNA, William S., 2016. *Introduction to fluid mechanics*. Boca Raton, Fla. [u.a.]: CRC Press, Taylor & Francis Group. ISBN 978-1-4822-1161-0
- KUNDU, Pijush K., Ira M. COHEN and David R. DOWLING, 2016. *Fluid mechanics*. Amsterdam [u.a.]: Elsevier/Academic Press. ISBN 0-12-405935-X, 978-0-12-405935-1
- FALKOVICH, Gregory, 2018. *Fluid mechanics* [online]. Cambridge: Cambridge University Press PDF e-Book. ISBN 978-1-316-41660-0. Available via: https://doi.org/10.1017/9781316416600.
- FALKOVICH, Gregory, 2018. *Fluid mechanics*. Cambridge; New York, NY; Melbourne, VIC; New Delhi; Singapore: Cambridge University Press. ISBN 978-1-107-12956-6
- HUTTER, Kolumban, WANG, Yongqi, 2016. *Fluid and Thermodynamics: Volume 1: Basic Fluid Mechanics* [online]. Cham: Springer PDF e-Book. ISBN 978-3-319-33633-6, 978-3-319-33632-9. Available via: https://doi.org/10.1007/978-3-319-33633-6.
- HUTTER, Kolumban, WANG, Yongqi, 2016. *Fluid and Thermodynamics: Volume 2: Advanced Fluid Mechanics and Thermodynamic Fundamentals* [online]. Cham: Springer PDF e-Book. ISBN 978-3-319-33636-7, 978-3-319-33635-0. Available via: https://doi.org/10.1007/978-3-319-33636-7.
- HUTTER, Kolumban and Yongqi WANG, 2016. *Fluid and thermodynamics*. [Cham]: Springer.

Compulsory:

None

Recommended:

None

Additional remarks:

None

Measurement Engineering

Module abbreviation:	MeasmEng_ESYS	**SPO-No.:**	22
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	3
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only winter term

Responsible for module:	Müller, Dieter
Lecturers:	Schwerd, Simon
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 47 h Self-study: 78 h Total effort: 125 h
Subjects of the module:	22: Measurement Engineering (MeasmEng_ESYS)
Lecture types:	SU/Ü/PR - seminar based teaching/Exercise course/laboratory
Examinations:	schrP90 - written exam, 90 minutes (MeasmEng_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

Engineering mathematics 1 and 2

Objectives:

Students will

- know the basic terms of measurement technology.
- know important measuring sensors and their characteristics for frequently occurring measured quantities in mechanical engineering.
- understand data sheets of measuring elements and devices.
- can select suitable measuring elements and devices for measuring tasks.
- can estimate, determine and evaluate measurement deviations.
- can apply the distribution function, also beyond measurement technology.

Content:

- Basic terms of measurement technology
- Measurement deviations including:
- Statistical principles for the treatment of random deviations.
- Error propagation, - linear regression, - dynamic behaviour and dynamic deviations of measuring elements
- Measurement of mechanical quantities
- Measurement of electrical quantities, digital measurement, measurement systems
- Temperature measurement
- Flow measurement
- Special sensors

Literature:

Compulsory:

None

Recommended:

- MATILDA, S. and others, 2021. *Basic Electrical Electronics and Measurement Engineering*. Chennai: Ugam Books. ISBN 8194482543
- BALAYI, B. and others, 2021. *Basic Electrical, Electronics and Instrumentation Engineering*. Chennai: Ugam Books. ISBN 8194482550

Additional remarks:

Note on bonus system for lab reports:

In the course, lab experiments can be set (in the laboratory or digitally), which must be completed and documented in written reports. Depending on the quality of the reports, bonus points can be earned for the examination performance. A maximum of 6 percent bonus points referred to the achievable points can be credited in the final examination.

Control Engineering

Module abbreviation:	ContrEng_ESYS	**SPO-No.:**	23
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	4
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only summer term

Responsible for module:	Navarro Gevers, Daniel
Lecturers:	Navarro Gevers, Daniel
Credit points / SWS:	5 ECTS / 5 SWS
Workload:	Contact hours: 58 h Self-study: 67 h Total effort: 125 h
Subjects of the module:	23: Control Engineering (ContrEng_ESYS)
Lecture types:	SU/Ü/PR - seminar based teaching/Exercise course/laboratory
Examinations:	schrP90 - written exam, 90 minutes (ContrEng_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

Mathematics and Electrical Engineering

Objectives:

The students

- know the basic concepts of control engineering.
- know the descriptions of linear control elements (dgl. and transfer function).
- model simple systems.
- know the behaviour of common control elements.
- understand the functioning of a control loop.
- know common controller types and can adjust the controllers.
- can design controllers in the frequency range and using root locus curves.
- can design pilot controls.
- can analyse the behaviour of non-linear control loops.

Content:

The control loop

- Detailed introductory example with simulation practical course
- Linear control loop elements with simulation practical course
- Stability
- Laplace transformation
- Frequency response
- Control loop analysis

- Controller design, also with Matlab (practical course)
- Nonlinear control loops
- rudiments of artificial intelligence

Literature:

Compulsory:

None

Recommended:

- OGATA, Katsuhiko, 2010. *Modern control engineering*. Boston [u.a.]: Pearson. ISBN 978-0-13-713337-6, 0-13-713337-5
- NISE, Norman, *Nise's control systems engineering*. ISBN 978-1-119-38297-3

Additional remarks:

The lecture is held in attendance and online.

Cost and Investment Management

Module abbreviation:	CostInvManag_ESYS	**SPO-No.:**	24
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	4
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only summer term

Responsible for module:	Weitz, Klaus Peter	
Lecturers:	Fischer, Sophia; Ketterle, Kiara	
Credit points / SWS:	5 ECTS / 4 SWS	
Workload:	Contact hours:	47 h
	Self-study:	78 h
	Total effort:	125 h
Subjects of the module:	24: Cost and Investment Management (CostInvManag_ESYS)	
Lecture types:	SU/Ü - lecture with integrated exercises	
Examinations:	schrP90 - written exam, 90 minutes (CostInvManag_ESYS)	
Special features of the examination performance:	None	

Recommended prerequisites:

None

Objectives:

The students

- recognize the necessity of cost management and cost control in an international environment.
- can read and interpret balance sheets, profit and loss statements and cash flow statements of companies.
- understand the tasks and structure of a company's internal accounting system.
- can calculate the costs of a product and understand the different factors influencing the total costs of a product.
- recognize their own contribution and responsibility in product development to product costs and life cycle costs.
- recognize factors influencing product costs and methods for reducing costs.
- are able to apply methods to determine target costs and increase the value of products.
- understand the necessities and challenges of investments and can calculate the profitability of investments.

Content:

- Buyer and sales motivation, importance of customer value and customer orientation.
- External accounting: Balance sheet, profit and loss statement, cash flow statement, key performance indicator
- Tasks of internal accounting and differences compared to external accounting
- Implementation of internal accounting, cost type, cost center and product cost accounting

- Methods of calculating product costs
- Necessity of cost management
- Responsibility and influence of product development on product- and life cycle costs
- Methods of cost control in product development
- Methods of cost reduction in product development
- Influence of complexity and number of variants on product costs and methods of cost reduction
- Target costing and value analysis
- Investment management and investment process
- Methods for investment calculation

Literature:

Compulsory:

- EHRLENSPIEL, Klaus, KIEWERT, Alfons, LINDEMANN, Udo, 2007. *Cost-Efficient design* [online]. Berlin [u.a.]: Springer PDF e-Book. ISBN 3-540-34647-3, 978-3-540-34648-7. Available via: https://doi.org/10.1007/978-3-540-34648-7.
- SULLIVAN, William G., Elin M. WICKS and C. Patrick KOELLING, 2020. *Engineering economy*. New York, NY: Pearson. ISBN 978-1-292-26496-7

Recommended:

- Further literature will be announced in lecture.

Additional remarks:

None

Project

Module abbreviation:	Proj_ESYS	**SPO-No.:**	25
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	6
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	winter and summer term

Responsible for module:	Gaull, Andreas
Lecturers:	Göllinger, Harald; Horak, Jiri; Kessler, Phillip; Navarro Gevers, Daniel; Fuchs, Daniel; Niederländer, Simon; Schlingensiepen, Jörn; Suchandt, Thomas
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 47 h Self-study: 78 h Total effort: 125 h
Subjects of the module:	25: Project (Proj_ESYS)
Lecture types:	S/Pr - seminar/laboratory
Examinations:	Proj - Project report (5-25 pages) and presentation (15 min.) (Proj_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

None

Objectives:

Students work one semester on their own responsibility on a self-contained, complex task.
They are able to

- tackle complex tasks as a team during the course of one semester.
- quickly acquaint themselves with new topics and challenges.
- analyze, break down and solve topics which include both engineering as well as commercial aspects, leveraging methods and tools learnt during their basic studies.
- apply project management methods and work successfully together as team.
- structure and prioritize problems and create relevant solutions to the satisfaction of the project sponsor.
- apply soft skills and methods such as communication, teamwork, leadership, creativity techniques, conflict management and time management.
- convincingly discuss, present and document their project's results.

Content:

- A given topic will be tackled by a team during the course of one semester
- The topics differ from semester to semester. Typically, students select a topic out of a given list of topics.
- Topics are typical interdisciplinary, engineering & management challenges with practical relevance.

Literature:
Compulsory: None Recommended: • PEDRO YOBANIS PIÑERO PÉREZ, JANUSZ KACPRZYK, RAFAEL BELLO PÉREZ, and ILIANA PÉREZ PUPO, 2024. *Computational Intelligence in Engineering and Project Management*. Switzerland: Springer. ISBN: 978-3-031-50495-2 • YAZDI, MOHAMMAD, 2024. *Progressive Decision-Making Tools and Applications in Project and Operation Management : Approaches, Case Studies, Multi-criteria Decision-Making, Multi-objective Decision-Making, Decision under Uncertainty*. Switzerland: Springer. ISBN: 978-3-031-51719-8
Additional remarks:
None

Building Energy Technology and Smart Homes

Module abbreviation:	BETSH_ESYS	**SPO-No.:**	27
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	4
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only summer term

Responsible for module:	Schrag, Tobias
Lecturers:	Akbar, Shariq; Reum, Tobias
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 47 h Self-study: 78 h Total effort: 125 h
Subjects of the module:	27: Building Energy Technology and Smart Homes (BETSH_ESYS)
Lecture types:	SU/Ü/PR - seminar based teaching/Exercise course/laboratory
Examinations:	schrP90 - written exam, 90 minutes (BETSH_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

None

Objectives:

The students

- know different building envelope constructions and can calculate their thermal qualities.
- know the energy balance of a building and understand the underlying building physics principles.
- know the of relevance and influences of thermal comfort.
- know about supply and distribution of thermal energy in buildings.
- know the available systems and components for thermal energy supply by fossil and renewable sources.
- know about thermal energy storage in buildings.
- know about principles, constraints and planning of heat pumps.
- know devices for heat transfer in buildings and can dimension them.
- know the basics of ventilation systems.
- know energy standards in new and existing buildings.
- know how to calculate the size of a thermal energy supply system.
- can compare Smart Homes to traditional control concepts.

Content:

Constraints about buildings

- overview of building types and energy consumption in buildings
- heat consumption for warm water and heating

- thermal comfort: influences from inside and outside, calculation mechanism
- Overview of building energy law and building energy certificates
- basic about ventilation systems
- heat supply systems and their dimensioning
- plant- and system technique natural gas and oil boilers
- plant- and system technique gas and el. heat pumps
- plant- and system technique wood pellet boilers
- plant- and system technique wood chip boilers
- system technique district heating systems
- Radiators
- floor heating systems
- Basic HVAC Design
- Smart Home /building information systems
- Actors and sensors in buildings

Literature:

Compulsory:

None

Recommended:

- HENS, Hugo, 2024. *Building physics - heat, air and moisture: fundamentals, engineering methods, material properties and exercises*. Berlin, Germany: Ernst & Sohn. ISBN 978-3-433-03422-4, 3-433-03422-2
- AGARWAL, Parul, MITTAL, Mamta, AHMED, Jawed, IDREES, Sheikh Mohammad, 2022. *Smart Technologies for Energy and Environmental Sustainability* [online]. Cham: Springer International Publishing PDF e-Book. ISBN 978-3-030-80702-3. Available via: https://doi.org/10.1007/978-3-030-80702-3.
- KHAZAII, Javad, 2014. *Energy-efficient HVAC design: an essential guide for sustainable building* [online]. Cham: Springer International Publishing PDF e-Book. ISBN 978-3-319-11047-9, 978-3-319-11046-2. Available via: https://doi.org/10.1007/978-3-319-11047-9.
- JAIN, Arpit, SHARMA, Abhinav, JATELY, Vibhu, AZZOPARDI, Brian, 2024. *Sustainable energy solutions with artificial intelligence, blockchain technology, and internet of things* [online]. Boca Raton: CRC Press PDF e-Book. ISBN 978-1-003-35663-9. Available via: https://doi.org/10.1201/9781003356639.
- MORENO-MUÑOZ, Antonio and Neomar GIACOMINI, 2023. *Energy smart appliances: applications, methodologies, and challenges*. Piscatawy, NJ: IEEE Press. ISBN 978-1-119-89945-7, 9781119899440

Additional remarks:

None

Energy Markets and Coupling Sectors

Module abbreviation:	EngMaCS_ESYS	**SPO-No.:**	28
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	6
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only summer term

Responsible for module:	Huber, Matthias
Lecturers:	Denter, Niklas; Huber, Matthias
Credit points / SWS:	5 ECTS / 5 SWS
Workload:	Contact hours: 58 h Self-study: 67 h Total effort: 125 h
Subjects of the module:	28: Energy Markets and Coupling Sectors (EngMaCS_ESYS)
Lecture types:	SU/Ü/PR - seminar based teaching/Exercise course/laboratory
Examinations:	schrP90 - written exam, 90 minutes (EngMaCS_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

Basic knowledge of energy economics
Basic knowledge of energy production
Basic knowledge of business administration

Combination with other lectures/topics

Builds on and deepens other lectures:
Energy Distribution and CHP
SmartGrids and Wind Energy
Energy economics and renewable energies

Objectives:

The students

- understand the individual energy markets and the interactions through sector coupling.
- know the influence of the power grids and system security requirements.
- have an overview of the technologies that are relevant for sector coupling and know their economic opportunities.
- will be able to evaluate individual technologies from an economic and technical point of view and with regard to their environmental impact and will be familiar with the factors that influence economically successful operation.

Content:

Energy markets and regulatory framework:

- Fundamentals of markets, supply and demand curves, pricing
- Levelized Costs of Electricity
- How does the electricity market work, electricity prices
  - Electricity exchange, energy only markets
  - Influence of renewable energies, funding schemes
  - Influence of power grid and system security
  - Interaction with neighbouring countries
  - Electricity demand, electricity generation
- The heat market, heat prices, developments, influences
  - Heat demand
  - Heat generation
- The gas market, gas prices, developments, influences
- System services Electricity grid operation
- Fuel markets
- New markets: local electricity markets, hydrogen market in the mobility sector

Secure electricity transport in the public grid as an additional market:

- Generation structures (effect of RES generation, flexibility of power plants, profile electricity generation with renewables).
- Power distribution structures
- Measures for system security
  - System services (control power, reactive power, islanding and black start capability)
  - Capacity reserves, cold reserves
  - Disconnectable loads
  - Feed-in management
  - Smart markets

Renewable Support Schemes

Overview of sector coupling technologies

- Storage
- Batteries in electric vehicles
- Heat pump
- Power to Heat
- Power to Gas (methane, hydrogen)
- Power to Liquid
- CHP
- Smart Home (as controllable load)
- Industrial processes (system efficiency)
- Electric cars

The individual technologies are evaluated according to their technical characteristics:

- Responsiveness
- Energy to power ratio (full load hours, utilization capability)
- Demand response capability

Literature:

Compulsory:

- STOFT, Steven, 2010. *Power system economics: designing markets for electricity*. Piscataway, NJ: IEEE Press. ISBN 0-471-15040-1, 978-0-471-15040-4

- BRADFORD, Travis, 2018. *The energy system: technology, economics, markets, and policy*. Cambridge, MA: The MIT Press. ISBN 978-0-262-03752-5
- BHATTACHARYYA, Subhes C., 2019. *Energy economics: concepts, issues, markets and governance* [online]. London: Springer PDF e-Book. ISBN 978-1-4471-7468-4. Available via: https://doi.org/10.1007/978-1-4471-7468-4.

Recommended:

- Will be announced in lecture

Additional remarks:

None

Mobility within the Energy System

Module abbreviation:	MobES_ESYS	**SPO-No.:**	29
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	7
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only winter term

Responsible for module:	Gelner, Alexander
Lecturers:	Gelner, Alexander; Kocak, Laura; Zade, Michel
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 47 h Self-study: 78 h Total effort: 125 h
Subjects of the module:	29: Mobility within the Energy System (MobES_ESYS)
Lecture types:	SU/Ü/PR - seminar based teaching/Exercise course/laboratory
Examinations:	SA - Seminar paper with oral presentation (15 min), written elaboration (8-15 pages) or presentation (15-20 pages) (MobES_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

Basic battery knowledge
Basic knowledge of energy economics
Basic knowledge of renewable energies
Basic knowledge of business administration

Combination with other lectures/topics
Builds on and deepens other lectures:
o Energy distribution and CHP
o Smart Grids and Wind Energy
o Energy systems and energy economics
o Energy markets and sector coupling (very important)

Objectives:

The students

- will have knowledge of different technologies for reducing CO2 emissions in the field of mobility, like electromobility, renewable gases (methane and hydrogen) and renewable liquid fuels.
- will be able to classify the different technologies and evaluate their interactions with the energy system as well as their economic impacts.
- will also be able to evaluate the electrical loads resulting from "fuel production" using renewable electricity.
- will understand in detail the technological and economical aspects of E-mobility and its impact on the energy system.

- will have an overview of possible changes in future mobility on the energy system areas: power generation, grid and consumption.

Content:

Future mobility

- From the perspective of electricity demand
- Presentation of mobility options
- CO2 emissions and CO2 reduction

Legal and regulatory framework:

- Promotion of e-mobility
- Biofuel quota law, sustainability requirement
- Grid fees (electricity, gas), levies, taxes, energy tax
- Emission reduction requirements, fleet consumption
- Promotion of e-vehicles and promotion of gas-powered vehicles

The different energy sources for the mobility of the future are discussed:

Liquid fuels in internal combustion engines (overview):

- Biofuels (overview only, review of biomass lecture).
  - Ethanol in mobility, ethanol production
  - Biodiesel in mobility, biodiesel production
  - Second generation fuels (fuels from residues)
- Synthetic fuels
  - Synthetic fuels
  - Power to Liquid

E-mobility:

- Technology
- Effect on the power grid
- Billing

Gas Mobility:

- Introduction to gas vehicle technology using internal combustion engine and fuel cell:
- Tank technology
- Renewable gas production

Literature:

Compulsory:

- DOPPELBAUER, Martin, 2024. *Introduction to Electromobility*. 2025. Edition. Wiesbaden: Springer. ISBN 978-3-658-45481-4
- KLELL, Manfred, 2023. *Hydrogen in Automotive Engineering*. Wiesbaden: Springer. ISBN 978-3-658-45481-4
- HEYWOOD, John, 2018. *Internal Combustion Engines Fundamentals*. New York: McGrawHill Education. ISBN 978-1-26-011610-6

Recommended:

- Further literature will be announced in the lecture.

Additional remarks:

None

Energy from Biomass and Biogenic Residues

Module abbreviation:	EBBR_ESYS	**SPO-No.:**	30
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	7
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only winter term

Responsible for module:	Goldbrunner, Markus	
Lecturers:	Goldbrunner, Markus	
Credit points / SWS:	5 ECTS / 5 SWS	
Workload:	Contact hours:	58 h
	Self-study:	67 h
	Total effort:	125 h
Subjects of the module:	30: Energy from Biomass and Biogenic Residues (EBBR_ESYS)	
Lecture types:	SU/Ü/PR - seminar based teaching/Exercise course/laboratory	
Examinations:	schrP90 - written exam, 90 minutes (EBBR_ESYS)	
Special features of the examination performance:	None	

Recommended prerequisites:

Thermodynamics I, Thermal Energy Technologies and Power Plants

Objectives:

The students

- are able to classify and evaluate the importance of bioenergy in today's and future energy supply.
- know the most important renewable raw materials, their properties and sources of supply.
- know the most important process engineering principles of the use of biomass (combustion, gasification, fermentation, fuel production) and can apply them.
- know the technical concepts and the most important details of the various bioenergy plants for heat, electricity and fuel production and can use them in plant planning and evaluation.
- can conceptualise a bioenergy plant, evaluate it economically and present the concept.

Content:

Introduction

- Greenhouse effect and renewable energies (focus on biomass, cycle)
- Properties and cultivation of renewable raw materials, problems
- Pathways of biomass use
- Organic residues, food waste and biowaste as feedstocks for energy use
- Basic economic considerations
- Aspects of licensing law

Heat generation

- Combustion concepts for large-scale plants
- Combustion concepts for small-scale plants

- Heat grids

Power generation through combustion

- Fundamentals of combustion
- Emissions
- Special features and design of the firing system
- Plant technology
- Use of waste wood and other residues

Power generation through thermal gasification

- Fundamentals of gasification, reaction kinetics
- Gasifier concepts
- Plant technology
- Utilisation of the gas
- Emissions

Power generation through fermentation (biogas)

- Substrate preparation / utilisation
- Basics of fermentation
- Plant technology
- Biogas pre-treatment, drying, cleaning (desulphurisation), special features of organic residues
- Gas treatment to natural gas quality (CO2 separation, different processes)

Fuels from renewable raw materials

- Basics of fuel production, synthesis
- Biomethane as fuel, filling stations for agriculture (biogas filling stations)
- 1st generation fuels
- 2nd generation fuels

Seminar: Planning a bioenergy production plant

- Plant planning according to HOAI
- Economic efficiency calculation according to VDI 2067
- Conceptual design and presentation of the concept
- Approval

Literature:

Compulsory:

- WELLINGER, Arthur, 2013. *The biogas handbook: science, production and application*. Oxford [u.a.]: Woodhead Publ. ISBN 978-0-85709-498-8
- SPLIETHOFF, Hartmut, 2010. *Power generation from solid fuels*. Berlin [u.a.]: Springer. ISBN 978-3-642-02855-7

Recommended:

- Further literature will be announced in the lecture.

Additional remarks:

None

Solar Buildings and Energy Consulting

Module abbreviation:	SolBuEC_ESYS	**SPO-No.:**	31
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	6
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	only summer term

Responsible for module:	Schrag, Tobias
Lecturers:	Mehta, Kedar; Schrag, Tobias
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 47 h Self-study: 78 h Total effort: 125 h
Subjects of the module:	31: Solar Buildings and Energy Consulting (SolBuEC_ESYS)
Lecture types:	SU/Ü/PR - seminar based teaching/Exercise course/laboratory
Examinations:	mdlP - oral exam, 15 minutes (SolBuEC_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

None

Objectives:

The students

- know different building concepts like passive houses, solar active houses or plus energy houses.
- can apply the rules of energetic refurbishment and energy consulting.
- learn the calculation of the heat energy demand, end energy and primary energy consumption according to DIN18599.
- analyse the thermal weaknesses of a building and define an individual refurbishment concept.
- know about building simulation through practical experience.
- can use KPIs for evaluation autonomy and economy of building related PV installations.
- know about energy plus district concepts and the integration of advanced technologies like PVT, ice storages or dual source heat pumps.
- know the differences of energy concepts for residential and non-residential buildings and know about HVAC concepts for office buildings.

Content:

- application of the German building energy law
- heat bridges in new and existing buildings
- deficits and inefficiencies of heating systems
- energy certificates
- low investment refurbishment measures
- comparison of calculated and measured heat energy consumption

- ventilation concepts
- investment calculation according to VDI 2067

Literature:

Compulsory:

None

Recommended:

- BEAUSOLEIL-MORRISON, Ian, 2021. *Fundamentals of building performance simulation*. New York; London: Routledge. ISBN 978-1-00-016928-7, 978-1-003-05527-3
- HACHEM-VERMETTE, Caroline, 2020. *Solar buildings and neighborhoods: design considerations for high energy performance*. Cham, Switzerland: Springer. ISBN 978-3-030-47018-0
- YUDELSON, Jerry, 2009. *Green building trends: Europe*. Washington, DC: Island Press. ISBN 978-1-61091-134-4, 1-61091-134-2
- EICKER, Ursula, 2014. *Energy efficient buildings with solar and geothermal resources*. Chichester, West Sussex, United Kingdom: John Wiley & Sons Inc.. ISBN 978-1-118-35224-3, 978-1-118-70707-4

Additional remarks:

None

Internship

Module abbreviation:	Intsh_ESYS	SPO-No.:	33
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	5
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	winter and summer term

Responsible for module:	Kerschenlohr, Annegret	
Lecturers:		
Credit points / SWS:	24 ECTS / 0 SWS	
Workload:	Contact hours:	0 h
	Self-study:	600 h
	Total effort:	600 h
Subjects of the module:	33: Internship (Intsh_ESYS)	
Lecture types:	Pr - laboratory	
Examinations:	PrB - Internship report (Intsh_ESYS)	
Special features of the examination performance:	None	

Recommended prerequisites:

None

Objectives:

The students

- receive an introduction to engineering-related work based on specific tasks.
- obtain an insight into technical interrelations, working methods and operational processes of a company with reference to possible fields of application for future graduates. Exemplary fields of application are in the areas of energy supply, energy plant production, energy system solutions, energy management, energy consulting, energy management.
- enhance and put to use their technical skills from the course.

Content:

- Independent participation on projects and problems, whose topics are closely related to the degree program or represent a valuable addition. Exemplary problems come from the following areas: energy supply, energy plant production, energy system solutions, energy management, energy consulting, energy management.
- Application and deepening of knowledge, methods and procedures that are taught and imparted in theoretical studies.

Literature:

Compulsory:

None

Recommended:

- Company-specific

Additional remarks:

Additional information:

- The internship can be carried out at approved companies only.
- The professional qualification of the supervisor should correspond to the relevant bachelor's degree.
- Universities and affiliated institutes are not permitted.

Study and examination achievements:

- Internship contract
- The practical semester of the second part of the program covers a period of 20 weeks and is accompanied by courses.
- Transcript
- Internship report

Practical Seminar

Module abbreviation:	PracSem_ESYS	**SPO-No.:**	34
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	5
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	winter and summer term

Responsible for module:	Gelner, Alexander
Lecturers:	
Credit points / SWS:	2 ECTS / 2 SWS
Workload:	Contact hours: 23 h Self-study: 27 h Total effort: 50 h
Subjects of the module:	34: Practical Seminar (PracSem_ESYS)
Lecture types:	S - seminar (PracSem_ESYS)
Examinations:	LN - participation without/with success (PracSem_ESYS)
Special features of the examination performance:	Will be announced by the respective speakers.

Recommended prerequisites:

None

Objectives:

The practical seminar teaches skills relevant to the work of an engineer. At the end of the course, students will be able to

- work independently on complex technical tasks in a team.
- apply their technical knowledge to specific problems.
- strengthen their social, personal and methodological skills (e.g. by moderating, presenting).
- implement technical tasks in a team and solve problems through teamwork.
- to reproduce real processes through simulations.
- use alternative teaching and learning platforms.

Dual study students already have in-depth knowledge of professional skills due to their extensive practical experience. In the selected seminars, it is therefore possible to go deeper into the content covered in each case or to select specific modules that can be expanded upon.

Content:

3-day block course on professional field-oriented skills in which students work on a task in a team. The events can include workshops, seminars, excursions and further education courses and, in addition to technical tasks, include topics such as moderation, presentation, conflict management, rhetoric, scientific work, ethics of technical issues, entrepreneurship, etc.

It is necessary to register for the practical seminar when registering for the examination (WS Nov / SS May) before starting the block lecture.

Adapted course for dual students: Due to the extensive practical experience, there is the option for dual students to shorten the seminar times to a 1-day event. This can be chosen from the courses offered by the Faculty of Mechanical Engineering or the Career Service.
Literature:
Compulsory: None Recommended: • DOBELLI, Rolf, 2014. *The Art of Thinking Clearly*. New York: Harper Collins Publ. USA. ISBN 9780062343963 • STRUNK JR., William and E. B. WHITE, 1999. *The elements of style*. Munich: B & T. ISBN 978-0-205-31342-6 • Additional literature will be announced in the specific lecture.
Additional remarks:
None

Project- and Quality-Management

Module abbreviation:	PQM_ESYS	**SPO-No.:**	35
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	5
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	winter and summer term

Responsible for module:	Weitz, Klaus Peter
Lecturers:	Wächter, Gerhard; Weitz, Klaus Peter
Credit points / SWS:	4 ECTS / 4 SWS
Workload:	Contact hours: 47 h Self-study: 53 h Total effort: 100 h
Subjects of the module:	35: Project- and Quality-Management (PQM_ESYS)
Lecture types:	SU/Ü - lecture with integrated exercises
Examinations:	schrP90 - written exam, 90 minutes (PQM_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

None

Objectives:

The students

- learn basic terms and use subject-specific terminology confidentlygain an overview of the interrelations-ships of project business and process thinking.
- obtain deep knowledge in the areas of communication, leadership and consequent customer orientation.
- can calculate and evaluate project structures and networking plans.
- learn the correct use of tools such as MS-Project.
- are able to assess the functionality of modern, innovative project and quality management.
- develop principles of action and methods for project managers and quality representatives.

Content:

- Project definition and project organization
- Work breakdown structure, planning of schedules, operation chart (CPM, MPM)
- Planning of cost and efforts, Milestones, project control through e.g. earned value method and milestone trend analyses
- Risk management in projects, FMEA
- Claim and change management
- Project completion techniques and acceptance procedures
- Development of quality understanding, TQM philosophy, BSC

- Quality management systems, QM implementation, ISO 9001
- Q methods such as FTA, TRIZ, SPC and QFD
- Process management with selected tools
- lean six sigma

Literature:

Compulsory:

None

Recommended:

- SCHELLE, Heinz, Roland OTTMANN and Astrid PFEIFFER, 2006. *Project manager*. Nuremberg: GPM. ISBN 978-3-924841-30-0, 3-924841-30-6
- KERZNER, Harold, 2022. *Project management: a systems approach to planning, scheduling, and controlling*. Hoboken, New Jersey: Wiley. ISBN 978-1-119-80537-3

Additional remarks:

None

Bachelor's Thesis Seminar

Module abbreviation:	BaThesSem_ESYS	**SPO-No.:**	32.1
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	7
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	winter and summer term

Responsible for module:	Navarro Gevers, Daniel
Lecturers:	
Credit points / SWS:	3 ECTS / 2 SWS
Workload:	Contact hours: 23 h Self-study: 50 h Total effort: 75 h
Subjects of the module:	32.1: Bachelor's Thesis Seminar (BaThesSem_ESYS)
Lecture types:	S - seminar
Examinations:	Coll - colloquium to graduation thesis (BaThesSem_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

None

Objectives:

Students taking part of this module

- deepen the methods of scientific work in engineering.
- are enabled to conduct methodical literature research.
- develop a clear outline in short periods of time as a basis for the bachelor thesis.
- lead professional discussions on the thematic structure.

Content:

Introduction/information session on Moodle online course:

Moodle/Faculty of Mechanical Engineering/Seminar Bachelor Thesis.

- Scientific requirements for the bachelor thesis ("Guidelines for bachelor theses")
- Legal framework for examinations
- Introduction to research and documentation techniques (short presentation of the services of the university library)

Search for a topic:

- Individual choice of topic and supervisor
- Independent contacting of companies and professors

Getting to know:

- Individual contact with the supervising lecturer and topic proposal
- Elaboration and written formulation of the topic
- Preparation and coordination of a time schedule for the Bachelor thesis
- Preparing the outline of the Bachelor thesis
- Preparing the registration of the Bachelor thesis

Literature:

Compulsory:

None

Recommended:

- GULSUN KURUBACAK-MERIC, and SERAP SISMAN-UGUR. *Improving scientific communication for life-long learners*. ISBN 1-79984-535-4
- GILPIN, Andrea. *A Guide to Writing in the Sciences*. ISBN 9781442627611

Additional remarks:

none

Bachelor's Thesis

Module abbreviation:	BT_ESYS	**SPO-No.:**	32.2
Curriculum:	**Programme**	**Module type**	**Semester**
	Energy Systems and Renewable Energies (SPO WS 21/22)	Compulsory Subject	7
Modulattribute:	**Language of instruction**	**Duration of module**	**Frequency of offer**
	English	1 semester	winter and summer term

Responsible for module:	Navarro Gevers, Daniel
Lecturers:	
Credit points / SWS:	12 ECTS / 0 SWS
Workload:	Contact hours: 0 h Self-study: 300 h Total effort: 300 h
Subjects of the module:	32.2: Bachelor's Thesis (BT_ESYS)
Lecture types:	
Examinations:	BA - Bachelor-Thesis (BT_ESYS)
Special features of the examination performance:	None

Recommended prerequisites:

None

Objectives:

With the bachelor thesis, students should demonstrate that they have the skills to work on a problem from the field of engineering in a qualified manner using scientific methods within a reasonable period of time.

The students should be able to solve a problem from the field of mechanical engineering using engineering methods independently, systematically and creatively.

The thesis should preferably deal with practical problems in the company.

The preparation of the bachelor thesis is supervised and evaluated by a professor at Ingolstadt University.

Content:

Engineering graduation thesis

For dual students, the thesis is to be prepared in cooperation with the respective dual company. The detailing of the content and the scientific standard is ensured in cooperation between the company's supervisor and the first examiner at the university of technology.

Literature:

Compulsory:

None

Recommended:

- KURUBACAK-MERIC, GULSUN; SISMAN-UGUR, SERAP (1981-). *Improving scientific communication for lifelong learners*. ISBN 1-79984-535-4
- GILPIN, ANDREA; PATCHET-GOLUBEV, PATRICIA. *A Guide to Writing in the Sciences*. ISBN 9781442627611

Additional remarks:

Details on the preparation of the bachelor thesis can be obtained via Moodle in the area of the Faculty of Mechanical Engineering and via the information in the bachelor seminar.