Module Catalog

M.Sc. Sustainable Energy and Processes

TUM Campus Straubing for Biotechnology and Sustainability (TUMCS)

Technische Universität München

www.tum.de/
www.cs.tum.de/

Module Catalog: General Information and Notes to the Reader

What is the module catalog?
One of the central components of the Bologna Process consists in the modularization of university curricula, that is, the transition of universities away from earlier seminar/lecture systems to a modular system in which thematically-related courses are bundled together into blocks, or modules.
This module catalog contains descriptions of all modules offered in the course of study.
Serving the goal of transparency in higher education, it provides students, potential students and other internal and external parties with information on the content of individual modules, the goals of academic qualification targeted in each module, as well as their qualitative and quantitative requirements.

Notes to the reader:

Updated Information
An updated module catalog reflecting the current status of module contents and requirements is published every semester. The date on which the module catalog was generated in TUMonline is printed in the footer.

Non-binding Information
Module descriptions serve to increase transparency and improve student orientation with respect to course offerings. They are not legally-binding. Individual modifications of described contents may occur in praxis.
Legally-binding information on all questions concerning the study program and examinations can be found in the subject-specific academic and examination regulations (FPSO) of individual programs, as well as in the general academic and examination regulations of TUM (APSO).

Elective modules
Please note that generally not all elective modules offered within the study program are listed in the module catalog.

Index of module handbook descriptions (SPO tree)

Alphabetical index can be found on page 78

Compulsory Courses | Pflichtmodule

Module Description

CS0010: Advanced Downstream Processing | Advanced Downstream Processing [ADSP]

Advanced Downstream Processing

Version of module description: Gültig ab summerterm 2025

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 90	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The teaching content will be evaluated by a written examination for the learning outcomes of the module of a duration of 60 minutes. Based on questions to advanced methods of downstream processes the students prove that they know the corresponding technical terms, designations and contents, that they have understand the complex relations and are able to apply their knowledge. Using calculations, the students also show that they can calculate, design and up-scale downstream processing methods.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Module Downstream Processing

Content:
The lecture gives a deep and detailed insight into advanced downstream processing technologies of bioprocesses. The content includes methods of integrated product recovery, enzyme immobilization and process intensication methods. One focus is on avoiding, minimizing and recycling waste streams in order to develop sustainable bioprocesses that conserve resources and do not pollute the environment. In the parallel exercise, the lecture content is deepened in the form of exercises to be worked on.

Intended Learning Outcomes:
After participating in the module events, the students are able to design advanced downstream processing technologies of bioprocesses. These include integrated downstream processing methods which improve the productivity of fermentation or enzymatic processes. At the end of the module, the students are able to develop, design, scale-up and implement economical and sustainable bioprocesses based on the application and implementation of these processing methods.

Teaching and Learning Methods:
The lecture takes place mainly as frontal teaching in order to familiarize the students with all the necessary basics, which they need for the assessment of targeted and sustainable downstream processes in the field of biotechnology. In the exercise, design tasks are worked on in order to learn how to calculate and design DSP processes.

Media:
slides, interactive quizzes, short films, scripts, exercise tasks

Reading List:
Harrison, Roger G, and others, Bioseparations Science and Engineering, 2nd edn (New York, 2015; online edn, Oxford Academic, 12 Nov. 2020), https://doi.org/10.1093/oso/9780195391817.001.0001, accessed 8 July 2024.

Responsible for Module:
Prof. Dr.-Ing. Michael Zavrel

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Module Description

CS0011: Conceptual Design of Bioprocesses | Conceptual Design of Bioprocesses [CDBP]

Version of module description: Gültig ab summerterm 2023

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 90	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The exam performance is effected by an written exam (60 min). It is reviewed wheter the students know the fundamentals of chemical and bioprocess engineering and if they can apply this knowledge on the design and evaluation of complex processes.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Module "Bioprocess Engineering"

Content:
Basics of conceptual design of bioprocesses; Basics of computational process design including calculation of process parameters; transfer of fundamental scale-up criteria towards real problem solving; Balancing of all process streams; Deepened knowledge of engineering principles and efficient energy utilization; State-of-the-art examples for sustainable bioprocesses will be given which utilize agricultural residues, waste streams or synthesis gas, and, thus, protect the climate.

Intended Learning Outcomes:
The students are qualified to understand the fundamentals of design and calculations of biotechnological processes after the course. They will aquire knowledge of all aspects of process design.

Teaching and Learning Methods:
The module consits of lectures and tutorials. Contents of the lecture shall be imparted in speech and by presentation. In the exercises, performed as part of the module, learned theory shall directly be applied with a practical orientation by means of calculations and examples from

targeted aspects of bioprocess design. Additionally the students will be qualified by an in-depth knowledge of the design of unit operations including calculation of process parameters based on utilization of selected software tools (such as SuperPro Designer).

Media:
slides, interactive quizzes, scripts, practical exercises

Reading List:
Elmar Heinzle, Arno P. Biwer, Charles L. Cooney. Development of Sustainable Bioprocesses: Modeling and Assessment. Online ISBN:9780470058916

Responsible for Module:
Prof. Dr.-Ing. Michael Zavrel Venessa Dsouza

Courses (Type of course, Weekly hours per semester), Instructor:
Conceptual Design of Bioprocesses (Exercise) (Übung, 2 SWS)
Dsouza V, Zavrel M

Conceptual Design of Bioprocesses (Lecture) (Vorlesung, 2 SWS)
Zavrel M
For further information in this module, please click campus.tum.de or here.

Module Description

CS0132: Energy Process Engineering | Energy Process Engineering [EP]

Energy Process Engineering

Version of module description: Gültig ab summerterm 2025

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 105	**Contact Hours:** 75

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Assessment takes the form of a written examination (90 minutes). Students demonstrate their ability to solve basic calculations and apply methods of process technology to different issues. In addition, some questions on energy and process technology plants are to bei answered in a written form.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Technical Thermodynamics and Balancing, Energy and Economics

Content:
Students learn about the properties of solid fuels, fuel preparation and the fundamentals of thermal and thermochemical conversion as well as the technical components involved - such as furnaces, gasifiers, heat exchangers, gas treatment plants, exhaust gas purification plants, reactors and synthesis stages, combined heat and power generation, the planning of local heating networks and emission regulation aspects. The practical exercises focus on the design and planning of plants.

Intended Learning Outcomes:
Students can understand thermal and chemical processes for energy and fuel production from biomass and other solid fuels and are able to recognize and explain the necessary requirements and process steps and technologies. They have a broad overview of the technical possibilities and necessary boundary conditions. They are therefore able to develop an appropriate concept, argue for it and estimate the economic benefits.

Teaching and Learning Methods:
The module consists of lectures and exercises. The content is taught in lectures and presentations.

Media:
Lecture, digital whiteboard, presentation

Reading List:
Spliethoff, H., Power generation from Solid Fuels, Springer, ISBN 978-3-642-02855-7, 2010
Karl, J.: Dezentrale Energiesysteme, Oldenbourg, ISBN 3-486-27505-4, 2004/

Responsible for Module:
Matthias Gaderer

Courses (Type of course, Weekly hours per semester), Instructor:
Energy process engineering (Exercise) (Übung, 3 SWS)
Gaderer M [L], Gaderer M

Energy process engineering (Lecture) (Vorlesung, 2 SWS)
Gaderer M [L], Gaderer M
For further information in this module, please click campus.tum.de or here.

Module Description

CS0260: Energy and Economics | Energy and Economics [EE]

Energy & Economis

Version of module description: Gültig ab summerterm 2025

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 90	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The examination takes the form of a written examination lasting 90 minutes. Students demonstrate that they understand and can answer questions and correlations between energy conversion, the conversion of renewable raw materials, energy supply in general and the energy industry situation. In addition, they will be able to explain technological and functional aspects of various energy conversion technologies.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Prior participation in the module Technical Thermodynamics and Balancing is strongly recommend.

Content:
The basics of energy sources, climate change and the technology of the heat, electricity and fuel markets as well as the use of renewable raw materials are explained, including an introduction to technical systems and current topics in the energy industry. Economic aspects such as electricity trading, CO2 trading and the current situation of various energy technologies are discussed. In the exercises, examples of energy technology tasks and their economic efficiency - such as the production costs of heat and electricity plants - are calculated.

Intended Learning Outcomes:
By participating in the module, students are able to understand and explain the resources for energy use, the principles of energy conversion into heat and electricity and the technical processes involved. They can carry out engineering-oriented economic assessments of energy systems based on different costs and revenues and understand the associated market mechanisms of the electricity and heat market.

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Teaching and Learning Methods:
The module consists of a lecture with exercises. The contents of the lecture are conveyed through presentations, calculations and small group work.

Media:
Presentations and calculation of examples in the form of digitally presented transcripts.

Reading List:
- Peter Zweifel , Aaron Praktiknjo , Georg Erdmann: Energy Economics, Theory and Applications, 2017, Springer
- Subhes C. Bhattacharyya: Energy Economics, Concepts, Issues, Markets and Governance, 2019, Springer
- Kaltschmitt, M.; Hartmann, H.; Hofbauer, H.: Energie aus Biomasse, 2. Auflage, Springer, ISBN 978-3-540-85094-6, 2009
- Karl, J.: Dezentrale Energiesysteme, Oldenbourg, ISBN 3-486-27505-4, 2004

Responsible for Module:
Matthias Gaderer, Bernhard Huber

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Module Description

CS0306: Energy and Process Engineering Project | Energy and Process Engineering Project [EPEP]

Energy and Process Engineering Project

Version of module description: Gültig ab winterterm 2025/26

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 8	**Total Hours:** 240	**Self-study Hours:** 120	**Contact Hours:** 120

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Based on the course content, student teams of two to a maximum of five students are assigned projects. The team size is based on the project task. Usual sizes are two or three students. Students apply the methods learned in the module (course 1+2) to carry out projects in teams. At the end of the project, a written project report of 30 - 60 pages on technology, operation, costs, economic efficiency and sustainability must be submitted and an oral presentation with a total duration of about 30 - 45 minutes (about 7 to 15 minutes per student) must be given. The assessment is based on the performance and elaboration of the project report and the presentation (80% / 20%). The examination can only be taken as a team and can only be repeated as a team.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Chemical- & Thermal Process Engineering, Mechanical Processing of biogenic Materials, Technical Thermodynamics and Balancing, Conceptual Design of Bioprocesses, Bioprocess Engineering

Content:
The module consists of three courses (LVs):
LV 1 Lecture: Advanced Process Engineering 2 SWS
LV 2 Exercise: Advanced Process Engineering 1 SWS
LV 3 Project work: Energy & Process Engineering Project 5
SWS
Total 8 SWS (8 ECTS)

Students learn the different design phases concept phase, basic engineering, detail engineering and
technical aspects such as P&Is, machinery directive, safety requirements and related aspects of control engineering, safety analysis, requirements for pressure equipment, legal aspects such as approval, environmental impact assessment, emission protection guidelines,
types of cost estimates, basic economic calculation methods and principles,
process optimization, lean tools, six sigma tools, project management and basic production models.

Intended Learning Outcomes:
After participating in the module courses, students have proven that they are able to carry out more complex engineering projects in the field of process engineering and/or energy technology, taking into account the aspects of technology, planning, costs, economic efficiency, operation, sustainability, approval, etc.. This may involve the planning of new production facilities, the conversion of production facilities for new purposes, the optimization of manufacturing or development processes, e.g. by eliminating waste within the framework of Lean or by applying Six Sigma tools.

Teaching and Learning Methods:
The lecture (LV1) and exercise (LV2) mainly take place as frontal teaching in order to familiarize the students with all the necessary basics they need for the evaluation of targeted and sustainable processes in the field of energy and process engineering. In the exercise, design tasks are worked on in order to learn how to calculate and design such processes. The assigned projects (LV3) is an elaboration of the project task to be carried out independently by the students. This is also intended to promote teamwork, project management skills and communication within the team. The project work is offered by the various professorships on campus and the project teams are supervised by the respective professorships that have developed the project task.

Media:
slides, interactive quizzes, short films, scripts, exercise tasks, team work, project conduction

Reading List:
Peters, M. S., Timmerhaus, K. D., West, R. E., 2003. Plant Design and Economics for Chemical Engineers. McGraw-Hill Education. ISBN 9780072392661

Vasudevan, P. T., Ulrich, G. D., 2004. Chemical Engineering Process Design and Economics: A Practical Guide. United States: Process Pub.. ISBN 9780970876829

Penney, W. R., Couper, J. R., Fair, PhD, J. R., 2012. Chemical Process Equipment: Selection and Design. Netherlands: Elsevier Science. ISBN 9780123969590

Towler, G., Sinnott R., 2021. Chemical Engineering Design - Principles, Practice and Economics of Plant and Process Design. Elsevier. ISBN 9780128211793

Chmiel, H. Bioprozesstechnik. (2011). Germany: Spektrum Akademischer Verlag. ISBN 9783827424761

Responsible for Module:
Verantwortliche: Zavrel, Gaderer Mitwirkend: Zavrel, Gaderer, Burger, Kainz, Fang Wenwen, Vienken,

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Module Description

CS0307: Technical Thermodynamics and Balancing | Technical Thermodynamics and Balancing [TTB]

Technical Thermodynamics and Balancing

Version of module description: Gültig ab summerterm 2025

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 75	**Contact Hours:** 75

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The examination takes the form of a written examination. The students prove that they can solve calculation problems on technical thermodynamics and the mass and energy balances of energetic and chemical processes. This demonstrates that students have understood the principles of the fundamentals and their application. Type of examination: written, duration: 120 minutes, aids will be announced in the lecture.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Physical Chemistry, Mathematics, Fundamentals of Thermodynamics

Content:
The basics of thermodynamics are repeated and their application to technical and energy-related tasks is taught. The fundamentals focus on changes of state and the main laws of thermodynamics, which are required for subsequent calculations. The technical application focuses on the individual components of thermal cycles, such as piston compressors, compressors, turbines, fuel properties, combustion and cycles for power processes, heat pumps and refrigeration systems. Further aspects are the energy and mass balancing of process steps and complete systems. With this knowledge, the student is able to calculate energy processes and other systems.

Intended Learning Outcomes:
After completing this course, students will be able to explain and calculate the fundamentals of technical thermodynamics and their application in technical examples of thermal energy technology

as well as the function and use of different thermal technologies. They will be able to apply basic equations and carry out mass and energy balancing. A key learning objective is to carry out calculations using the simplest possible means (calculator) and to use and understand tables (steam tables), collections of material data and diagrams (Ts diagram).

Teaching and Learning Methods:
The lecture is mainly held in handwritten digital form, projected onto the screen.
This makes it easier to follow and strengthens the students' understanding of the procedure. Power Point slides are essentially dispensed with. In concrete calculation examples, the theory is applied step by step in technical examples. The function and structure of the technical systems to be calculated are explained in the basic principles. The lecturer classifies the results of exercises in the overall context.

Media:
A detailed script will be provided, digital blackboard in the lecture and the exercises.

Reading List:
- Script Technical Thermodynamics, Gaderer, RES, 2025
- VDI Heat Atlas: Springer, 2010
- Alan M. Whitman: Thermodynamics: Basic Principles and Engineering Applications, Springer 2023
- Atkins, Peter W.: Physical Chemistry, W. H. Freeman and Company, New York, ISBN, 1-4292-1812-6
- Atkins, Peter W.: Physikalische Chemie, VCH, ISBN 3-527-25913-9, 1990
- VDI Wärmeatlas, VDI-Gesellschaft Verfahrenstechnik und Chemie-Ingenieurwesen 9.Auflage, Springer-Verlag ISBN 3-540-41201-8 9.Auflage
- Pischinger, R.; Klell, M.; Theodor, S.: Thermodynamik der Verbrennungskraftmaschine, 3. Auflage, Springer-Verlag, ISBN 978-3211-99279-0, 2009
- Stephan, P.; Schaber, K.; Stephan, K.; Mayinger, F.: Thermodynamik, Band 1: Einstoffsysteme, 17. Auflage, Springer, ISBN 978-3-540-70813, 2006
- Baehr, Hans Dieter; Kabelac, Stephan: Thermodynamik, 14. Auflage, Springer, ISBN 978-3-642-00555-8, 2009
- Stephan, P.; Schaber, K.; Stephan, K.; Mayinger, F.: Thermodynamik Grundlagen und technische Anwendungen, Band 2: Mehrstoffsysteme und chemische Reaktionen, 15. Auflage, Springer, ISBN 978-3-540-36709-3, 2010
-Schnitzer, H.: Grundlagen der Stoff- und Energiebilanzierung, 9. Auflage, Vieweg, ISBN 3-528-04794-1, 1991
- Kaltschmitt, M.; Hartmann, H.; Hofbauer, H.: Energie aus Biomasse, 2. Auflage, Springer, ISBN 978-3-540-85094-6, 2009
- Karl, J.: Dezentrale Energiesysteme, Oldenbourg, ISBN 3-486-27505-4, 2004

Responsible for Module:
Matthias Gaderer

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Module Description

CS0311: Mechanical Processing of Biogenic Materials | Mechanical Processing of Biogenic Materials [MVTbM]

Mechanical Process Engineering biogenic Materials

Version of module description: Gültig ab summerterm 2025

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 90	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Assessment takes the form of a written examination (90 minutes).
The students prove that they can solve computational problems and apply methods of biogenic particles and processing as well as answer questions about plants and apparatuses of mechanical process engineering.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Basic of Thermodynamics, Reaction Technology, Heat Transfer, Fluid Mechanics

Content:
The module provides the necessary basics for the description of particle systems in general and with a focus on biogenic particles
(particle size and shape, distribution functions, particle movement and interactions in bulk solids).
The basic operations applied to particles are presented: Production, comminution, mixing, separation, agglomeration, fixed and fluidized beds, filtration. For example, applications in the materials and energy industry in fiber technology, wood size reduction, conveying, stirring and combustion of biomass are discussed.

Intended Learning Outcomes:
After participating in the module, the students are able to apply the mathematical fundamentals of particle technology and to interpret the basic operations of particle process technology.

Teaching and Learning Methods:
The module consists of a lecture and a tutorial.
The contents of the module are conveyed in the lecture by means of papers and presentations. Students are encouraged to actively engage with the topics by integrating various tasks for self-research and comprehension questions. In the exercises, which take place alternately with the lecture, the understanding of the course content is deepened. Students work through various calculation tasks.

Media:
Presentations, scripts, exercises

Reading List:
Rhodes, M.J., 2008. Introduction to particle technology. 2nd ed. Chichester, England: Wiley. ISBN 047072711X.

Responsible for Module:
Matthias Gaderer, Wen Wen

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Module Description

CS0312: Conceptual Design of Fluid Seperation | Conceptual Design of Fluid Seperation

Version of module description: Gültig ab summerterm 2025

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 90	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The exam performance is effected by an oral exam. It is reviewed whether the students know the fundamentals of
conceptual design of chemical and biotechnological processes and if they can apply this knowledge on the design
and evaluation of complex processes. The exam consists of two parts: (a) 30 minutes preparation through solving a
given problem set (b) 30 minutes of oral examination. In the beginning of part (b) the results of part (a) are presented
by the student. (total duration 60 min)

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
Knowledge of thermodynamics and apparatusses used for fluid sparations processes. It is recommended to visit at
least the course "Introduction of Process Engineering" first.

Content:
Basics of cenceptual design of processes; Basics of computational process design including calculation of process
parameters; transfer of fundamental scale-up criteria towards real problem solving; Balancing of all process streams;
Deepened knowledge of engineering principles.

Intended Learning Outcomes:
The students are qualified to understand the fundamentals of design, calculations, and balancing of chemical
processes and fluid separation courses after the course. They will aquire knowledge of different challenges of process
design and how to master them.

Teaching and Learning Methods:
The module consists of lectures and parallel tutorials. Contents of the lecture shall be imparted in speech and by
presentation. In the exercises performed as part of the module learned theory shall directly be applied with a practical orientation by means of calculations and examples from targeted aspects of process design and calculation. based on a direct comparison of a chemical process with it´s biotechnical alternative they learn to apply their knowledge on
reality based challenges. Additionally they will be qualified by an in-depth knowledge of the design of operation units
including calculation of process parameters based on utilization of selected software tools.

Media:
Panel, slides, scripts, practical exercises

Reading List:
Moulijn et al. (2013). Chemical Process Technology. – John Wiley & Sons Ltd, The
Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom.
Biegler et al. (1997). Systematic Methods of Chemical Process Design. – Prentice
Hall.
Doherty, M.F., Malone, M.F. (2001). Conceptual design of distillation systems. –
Boston: McGraw-Hill.
Gmehling, J., Kolbe, B., Kleiber, M., Rarey, J. (2012). Chemical Thermodynamics
for Process Simulation. 1. Auflage. Weinheim: Wiley – VCH
Grassmann, P., Widmer, F., Sinn, H. (1997). Einführung in die Thermische
Verfahrenstechnik. 3. vollst. überarb. Auflage. Berlin: de Gruyter.
Stichlmair, J.G., Fair, J.R. (1998). Distillation: Principles and Practice. – New York:
Wiley – VCH.

Responsible for Module:
Prof. Jakob Burger

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Electives | Wahlmodule

Technical Electives | Fachspezifische Wahlmodule

Module Description

CS0003: Production of Renewable Fuels | Production of Renewable Fuels

Version of module description: Gültig ab winterterm 2023/24

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 90	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The learning results are going to be proven in form of a written exam of 90 Minutes. Along the problem set, it is checked whether the student is able to understand, improve and assess industrial processes for the production of renewable fuels. No aids permitted.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
Basic knowledge in chemistry, Fundamentals in Thermodynamics (e.g., Grundlagen der Thermodynamik), Fundamentals in Process Engineering (e.g., Introduction to Process Engineering)

Content:
Requirements for fuels, linkage of energetic and chemical value chains, fossil fuel production as reference, balancing and assessments (Well-to-Wheel), Hydrogen and methanol economy, alternative fuels on C1-basis, fisher-tropsch fuels, OME, bio-based oil fuels, biodiesel, green diesel, HEFA, bio-based alcohols, legislation of fuels.

Intended Learning Outcomes:
This module aims at making the students familiar with the industrial processes to produce renewable fuels. They are able to set up material and energy balances of these processes and assess their sustainability. Limitations with respect of raw material supply, energetic efficiencies

and market requirements are understood. The students understand the interactions of fuel market and energy market.

Teaching and Learning Methods:
The module consists of a lectures and exercises. Contents of the lecture shall be imparted in speech and by presentation. To deepen their knowledge students are encouraged to study the literature and examine with regards to content the topics. In the exercises learned theory is applied with a practical orientation by means of arithmetic examples.

Media:
Hybrid live lectures & asynchronous mini-videos allowing distance learning, lecture Script and exercises via online platform, excursions to fuel production plants

Reading List:
• Jacob A. Moulijn, Michiel Makkee, Annelies E. van Diepen: Chemical Process Technology, Wiley (2013).
• George Olah et al.: Beyond Oil and Gas: The Methanol Economy, Wiley VCH (2006)
• Volker Schindler: Kraftstoffe für morgen: Eine Analyse von Zusammenhängen und Handlungsoptionen, Springer (1997)
• Martin Kaltschmitt, Hans Hartmann, Hermann Hofbauer: Energie aus Biomasse; Grundlagen, Techniken und Verfahren,SpringerVieweg (2016)
• Jochen Lehmann, Thomas Luschtinetz: Wasserstoff und Brennstoffzellen, Springer (2014)

Responsible for Module:
Prof. Jakob Burger

Courses (Type of course, Weekly hours per semester), Instructor:
Production of renewable fuels (Tutorial, Straubing) (Übung, 2 SWS)
Burger J [L], Burger J, Groh D, Rosen N

Production of renewable fuels (Tutorial, Garching) (Übung, 2 SWS)
Burger J [L], Burger J, Groh D, Staudt J

Production of renewable fuels (Lecture, Garching) (Vorlesung, 2 SWS)
Burger J [L], Burger J, Staudt J

Production of renewable fuels (Lecture, Straubing) (Vorlesung, 2 SWS)
Burger J [L], Burger J, Staudt J
For further information in this module, please click campus.tum.de or here.

Module Description

CS0012: Artificial Intelligence for Biotechnology | Artificial Intelligence for Biotechnology [AI]

Version of module description: Gültig ab summerterm 2024

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 90	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The module examination takes the form of a presentation followed by discussion. The learning outcomes are verified by a group project (3-4 students per group). The presentation of the developed code and the results of the project will be done together as a group, with each group member presenting one part. The presentation should be equally divided among the group members. After the presentation, each group member is asked individual questions about the project. The final grade will be based on the presentation and results of the project (duration of presentation and questions: approx. 30 min depending on group size; approx. 8-10 minutes per student). As a voluntary mid-term effort, the students can take part in a multiple-choice test (duration: 10 minutes). If they achieve at least 65% of the points in this test, a bonus of 0.3 will be credited on the grade of the presantation (however, an improvement of the grade from 4.3 to 4.0 is not possible).

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
Mathematical Skills in Linear Algebra and Statistics as well as Programming Skills in Python are expected

Content:
Technologies that generate analyses or predictions based on data can be found in almost all areas of our daily life (e.g. recommender systems, autonomous driving, and credit card fraud detection). These methods are also important for analyzing biological and biomedical data, e.g. for finding novel patterns in biological data, predicting the disease state of a patient, or the 3D structure of proteins. In this course, we will learn the fundamentals of machine learning and will apply these methods to various real-world problems.

The following contents will be treated exemplarily:
- Similarity and Distance Metrics
- Data Preprocessing and Visualization
- Dimensionality Reduction (e.g., Principal Component Analysis)
- Classification (Nearest-Neighbor, Logistic Regression, Decision Trees, Support Vector Machines (SVM))
- Model Selection and Hyperparameter Optimization (Confusion Matrix and Evaluation Measures, Cross-Validation, Hyperparameter tuning techniques, Common problems such as Over- vs. Underfitting)
- Clustering (K-Means, Hierarchical Clustering)
- Regression Models (Linear Regression, Support Vector Regression)

AI-based technologies have the potential to support many areas of biotechnology and sustainability, e.g. by guiding downstream research with data-driven predictions or supporting decision-making with demand forecasts. In this course, we will look at suitable practical examples and demonstrate their potential.

Intended Learning Outcomes:
The students know the fundamental and most important artificial intelligence, especially machine learning, methods and are able to apply them independently on various real-world problems. The students learn the basics of the programming language Python (one of the leading programming languages in the field of machine learning) and are able to implement and apply machine learning algorithms in Python. In addition, students are able to visualize and interpret different types of data and results independently. Students will understand how artificial intelligence can support areas of biotechnology and sustainability and are able to assess the potential of AI-based approaches in sustainability projects.

Teaching and Learning Methods:
Lectures to provide the students with all necessary fundamentals of artificial intelligence, especially of machine learning which they will need to independently apply these concepts to real-world data. In the exercises the students are introduced to the programming language Python, as well as to apply and implement these algorithms for specific case studies.

Media:
The lecture shall mainly be done by using PowerPoint presentations. During the exercise the students work at PCs to gain confidence in using the programming language Python. Students implement various machine learning methods in Python (e.g. using Jupyter Notebooks) and apply them on various examples. Students work on real world problems to implement learnt skills and to gain confidence in applying these different methods independently.

Reading List:
Murphy, K. P. (2012). Machine learning: a probabilistic perspective. MIT press.
Bishop, C. M. (2006). Pattern recognition and machine learning. Springer.
Raschka, S. (2017). Machine Learning mit Python. mitp Verlag.

Friedman, J., Hastie, T., & Tibshirani, R. (2001). The elements of statistical. Springer.

Responsible for Module:
Prof. Dr. Dominik Grimm

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Module Description

CS0024: Electrobiotechnology | Electrobiotechnology [EBT]

Version of module description: Gültig ab winterterm 2023/24

Module Level: Master	Language: English	Duration: one semester	Frequency: summer semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 90	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The exam performance is effected by an written exam (90 min). It is reviewed whether the students know the fundamentals of electrochemistry and if they can apply this knowledge on the design and evaluation of electrobiotechnological processes.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:

Content:
Terms and definitions of electrochemistry and bioelectrochemistry; deepened knowledge of physical-chemical fundamentals of electrochemical equilibria and electrochemical processes and reactions; fundamentals of electrochemical thermodynamics and electrochemical kinetics; fundamentals of electrochemical methods (with special focus on biological problems); bioelectrochemical processes in biological systems, especially microorganisms and enzymes; fundamentals of eletrobiotechnology especially on reactions, reactor technology and balancing. Examples of electroorganic syntheses, inter-relations with other subject areas (e.g. environmental biology); exemplarily applications in biosensoris and electrobiorefineries.

Intended Learning Outcomes:
The students are qualified to understand the fundamentals of electrochemistry and electrobiotechnology after the course. They will aquire knowledge of the different application fields of electrocchemistry as well as electroanalysis. Additionally they will be qualified by an in-depth knowledge of bioelectrochemistry especially of natural cellular bioelectrochemical processes as well as bioelectrochemistry of enzymes and microorganisms in combination how to apply them in electrobiotechnology.

Teaching and Learning Methods:
The module consits of lectures and parallel tutorials. Contents of the lecture shall be imparted in speech and by presentation. In the exercises performed as part of the module learned theory shall directly be applied with a practical orientation by means of calculations and examples from targeted aspects of electrochemistry and electrobiotechnology.

Media:
Panel, slides, scripts, exercise sheets

Reading List:

Responsible for Module:
Prof. Nicolas Plumeré

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Module Description

CS0051: Corrosion and Surface Technology | Corrosion and Surface Technology [KorrOb]

Version of module description: Gültig ab winterterm 2024/25

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 60	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The learning outcome is determined by a 90-minute written examination.
In this exam, the students are required to demonstrate their knowledge of corrosion mechanisms through comprehension questions. Building on that, the ability to apply this knowledge to technical methods for corrosion prevention will be assessed.

Repeat Examination:
Next semester

(Recommended) Prerequisites:

Content:
This course provides an initial overview of the exciting field of corrosion. This course will provide the fundamentals to understand why corrosion is important, the social consequences that can arise from corrosion, the challenges and the economic consequences will be discussed. A sustainable approach to preventing corrosion will be discussed through the use of environmentally friendly coating materials and processes and minimizing waste and emissions. In addition, corrosion prevention can be achieved through the use of materials with longer service life and higher corrosion resistance.

Intended Learning Outcomes:
After completion of the module, students are enabled to explain the fundamental mechanisms of corrosion of engineering materials. They can name countermeasures, and explain their working mechanisms, as well as typical procedures for the treatment of material surfaces.

Teaching and Learning Methods:
The module consists of a lecture with integrated exercises. The learning content is conveyed through lectures. In the integrated exercises, students work on individual questions and present their solutions.

1) Lectures:
- Purpose: Lectures provide the essential theoretical foundation in sustainable energy materials, covering key topics like basic corrosion, corrosion protection, etc.
- Approach: Interactive and structured with clear explanations, visual aids, and real-world examples, lectures often include brief in-class exercises to reinforce understanding.
- Outcome Alignment: Lectures support learning outcomes related to understanding and explaining core concepts, while integrated exercises help students begin to apply and analyze these ideas.

2) Exercises and Problem-Solving Sessions:
- Purpose: These sessions reinforce lecture material, allowing students to practice problem-solving, apply theory to real-world scenarios, and deepen their understanding.
- Approach: A mix of individual and collaborative exercises, including problem sets, with guidance from instructors to support learning.
- Outcome Alignment: Exercises align with outcomes related to applying, analyzing, and evaluating knowledge, preparing students for advanced tasks in projects and labs.

Media:
1) Presentation Slides:
• Purpose: Presentation slides will be the primary medium for delivering content during lectures. They will be designed to visually complement the spoken content, providing clear and concise explanations of key concepts, diagrams, equations, and real-world examples.
• Usage: Slides will be used to illustrate complex ideas in electrochemistry, corrosion and corrosion protection, helping students to follow along and understand the material more effectively. Key points, equations, and visual aids will be highlighted to enhance comprehension.
• Accessibility: All slides will be made available to students before or after the lectures via the course's online platform, allowing for review and study at their own pace.
2) Online Learning Platform:
• Purpose: The online learning platform (e.g., Moodle) will serve as the central hub for course materials, communications, and assessments. It will facilitate a blended learning approach, integrating various media forms into a cohesive learning experience.
• Usage: The platform will host lecture slides, videos, reading materials, quizzes, and assignments. It will also be used for discussion forums where students can ask questions and engage in peer learning. This platform supports continuous access to resources and enables students to manage their learning effectively.
• Interactivity: Features such as quizzes, polls, and discussion boards will allow students to interact with the material and with each other, enhancing engagement and reinforcing learning.
3) Textbooks and Research Articles:

• Purpose: Textbooks and scholarly articles provide in-depth coverage of theoretical concepts and the latest research developments in the field. These resources are essential for supporting lecture content and offering additional perspectives on topics covered in the course.
• Usage: Core textbooks will be recommended for fundamental concepts, such as corrosion science. Research articles will be assigned to provide insights into recent advancements and emerging trends in corrosion. These readings will complement lecture content and form the basis for exercises and discussions.
• Depth: By engaging with these texts, students will deepen their understanding of the material and develop critical thinking skills, particularly in evaluating new research and technological developments.

Reading List:
- Introduction to Corrosion Science by Edward McCafferty
- Corrosion Science and Engineering by Pietro Pedeferri
- Corrosion Understanding the Basics by J. R. Davis

Responsible for Module:
Marc Ledendecker

Courses (Type of course, Weekly hours per semester), Instructor:
Corrosion and Surface Technology (Vorlesung mit integrierten Übungen, 4 SWS)
Ledendecker M [L], Ledendecker M
For further information in this module, please click campus.tum.de or here.

Module Description

CS0092: Wind Power | Wind Power [Wind]

Version of module description: Gültig ab summerterm 2024

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 4	**Total Hours:** 120	**Self-study Hours:** 82	**Contact Hours:** 38

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The basics of energy generation from wind are assessed in a written examination (60 minutes). Multiple-choice questions can also be asked. The students prove that they have understood the technology of wind turbines and that they are able to carry out calculations on the design, energy yield and economic efficiency of wind turbines. They also show that they have understood the special problems in the project planning phase as well as during operation within the framework of legal requirements, the requirements for nature and species protection as well as the local acceptance of wind power use and ecology and acceptance and that they are able to evaluate plants and sites in this respect.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Basics in Mathematics and Physics
Basics in Energy Technology

Content:
This module teaches in-depth knowledge about energy generation from wind power. The technology is described using the following points:
- Physical basics
- Designs and system components
- Planning, construction and operation
- Power output and energy supply
In addition to the technical characteristics of the plants, the module also focuses on their effects on the environment, legal framework conditions and economic

Intended Learning Outcomes:
Having attended the module, the students will be able to characterize and recognize different types of wind turbines and to understand them from a technical and energetic point of view. The students understand the processes involved in planning, erecting and operating wind turbines and are able to evaluate turbines from an economic and ecological point of view.

Teaching and Learning Methods:
The module consists of lecture and exercise. The contents of the lectures are primarily conveyed by the lecturers and through presentations. The students should get a well-founded insight into the topic. The exercises cover on the one hand technical calculations on wind turbines, on the other hand the different aspects of turbine project planning, in particular economic and ecological aspects, as well as acceptance by public. Among other things, plan and role plays in groups are planned to achive this goal. Some of the exercises are to be prepared by the students themselves, others are to be carried out as face-to-face exercises. This should encourage students to work independently and to deal more intensively with the respective topics. Simulation and role-playing games help students to gain a deeper understanding of the opportunities and problems in the field of wind power technology.

Media:
PowerPoint, blackboard, publications

Reading List:
Peter Schaffarczyk, Wind Power Technology, Springer, 2023, ISSN 1865-3529, ISSN 1865-3537 (electronic)

Responsible for Module:
Doris Schieder Doris.schieder@tum.de

Courses (Type of course, Weekly hours per semester), Instructor:
Windkraft Übung (Übung, 1 SWS)
Schieder D [L], Schieder D, Widmann A

Windkraft Vorlesung (Vorlesung, 1,5 SWS)
Schieder D [L], Schieder D, Widmann A
For further information in this module, please click campus.tum.de or here.

Module Description

CS0101: Renewables Utilization | Renewables Utilization

Version of module description: Gültig ab winterterm 2020/21

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 90	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Assessment takes a written examination (90 minutes), with students to unterstand and to apply structure, transformation and use of different renewable resources. Students are required to answer questions using individual formulations and outline structures and reactions. In addition, sample calculations are to be worked out.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Basic lectures in chemistry; Basics on renewables utilization

Content:
Various types of ingredients of renewable raw materials: sugars, polysaccharides, fats and oils, amino acids, proteins, terpenes, aromatics. The following topics will be dealt with in more detail: structure, composition, occurrence, properties, analysis and type of added value or use in various examples.

Intended Learning Outcomes:
After completion of the modules, students understand the chemical composition of renewable resources as well as their production and application. Using this knowledge students are able to explain the respective advantages and disadvantages as well as analyze the underlying physical, chemical and biotechnological principles of their conversion into valuable products.

Teaching and Learning Methods:
Lecture and accompanying tutorial including individual work on specific examples.

Media:
Presentation, script, examples and solutions

Reading List:

Responsible for Module:
Broder Rühmann

Courses (Type of course, Weekly hours per semester), Instructor:
Renewables Utilization (Exercise) (Übung, 2 SWS)
Rühmann B

Renewables Utilization (Lecture) (Vorlesung, 2 SWS)
Sieber V [L], Rühmann B, Sieber V
For further information in this module, please click campus.tum.de or here.

Module Description

CS0105: Modelling and Optimization of Energy Systems and Processes | Modelling and Optimization of Energy Systems and Processes [MOES]

Version of module description: Gültig ab summerterm 2025

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 120	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Assessment is done as a written examination (duration 90 minutes). The main part of the exam is to solve typical problems by applying the methods aquired in the course. This typically involves writing small Matlab programs on paper. All course materials (slides, programs) can be brought as printouts and used as templates for this. Additionally, questions have to be answered to check the understanding of basic methods and principles as learned during the course.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
Bachelor modules Mathematics & Physics; Module Basics of Numerical Methods, programming experience (ideally with Matlab)

Content:
Modelling and Simulation:
- physical models
- data-based models (look-up tables, polynomials, neural networks)
- methods for generating models

Optimization methods:
- linear optimization (linear regression)
- nonlinear optimization

Basics of process modelling & control theory
The methods treated in this course are complemented with practical examples that are chosen to show both the wide scope of application (engineering, natural sciences) and their relation to sustainability.

Intended Learning Outcomes:
After attending the course the participants understand basic methods for creating models, simulation and optimization. In addition, they are able to apply these methods by creating appropriate program code in Matlab. Furthermore, the participants acquire Matlab programming experience.

Teaching and Learning Methods:
The module consists of a lecture with embedded excercise. Lectures include presentations whose content is deepened by solving excercise problems autonomously in course. In order to improve the learning outcome, participants work at homework excercise problems. The solution is discussed in the following lecture.

Media:
PP presentation, blackboard, demonstration of programs

Reading List:
S. R. Otto & J.P. Denier, An Introduction to Programming and Numerical Methods in MATLAB, Springer, London, 2005
O. Nelles, Nonlinear System Identification, Springer, Berlin, 2010

Responsible for Module:
Prof. Josef Kainz

Courses (Type of course, Weekly hours per semester), Instructor:
Modelling and Optimization of Energy Systems (Vorlesung mit integrierten Übungen, 4 SWS)
Kainz J [L], Kainz J
For further information in this module, please click campus.tum.de or here.

Module Description

CS0108: Catalysis | Catalysis

Version of module description: Gültig ab summerterm 2022

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 105	**Contact Hours:** 45

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Results will be assessed by a written exam (90min), whereby the students explain important facts of technical catalysis chemistry, mechanistic aspects of catalysts how catalysts work, what is their typical composition and show practical applications by using examples.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Basic organic and inorganic chemistry

Content:
transition metal compounds, homogenous/heterogenous catalysis, mechanistic details of activation of organic and inorganic molecules at transition metal compounds, surface chemistry, characterisation of catalysts, heat/mass transfer at catalyst grains, reactor designs

Intended Learning Outcomes:
Students can show important chemical aspects of the phenomenon of catalysis with simple examples. They can show the implication of a catalyst in an overall reaction and can quantify it mathematically by using typical measurable values.

Teaching and Learning Methods:
Using lectures, basic principles of catalysts and catalysis will be transmitted.

Media:
Power point presentation, table, oral teaching, discussion

Reading List:
Dirk Steinborn, Grundlagen der metallorganischen Komplexkatalyse, Vieweg und Teubner Verlag, 2. Auflage 2009 (434 Seiten, 41 €).

Responsible for Module:
Prof. Herbert Riepl

Courses (Type of course, Weekly hours per semester), Instructor:
Catalysis (Lecture) (Vorlesung, 3 SWS)
Riepl H [L], Riepl H
For further information in this module, please click campus.tum.de or here.

Module Description

CS0109: Sustainable Energy Materials | Sustainable Energy Materials [SEM]

From the basics to the application

Version of module description: Gültig ab summerterm 2023

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 120	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The learning outcomes will be checked through a written exam (90 minutes) in which the students have to reproduce essential aspects of sustainable energy materials and their applications through examples. In addition, mathematical problems will be given to show that the students are able to quantify simple examples.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Knowledge of basic electrochemistry/physical chemistry is beneficial, but not required.

Content:
Sustainable energy management is an important issue to minimize environmental impact and climate change. Electrochemical devices such as fuel cells and batteries can help use Renewable In this course, you will learn about the basics of electrochemistry and various important devices used in current and future energy systems, such as fuel cells, batteries, and electrochemical water splitting. The lectures will cover the working principles, components, materials, applications, and future potential of these devices in the energy economy.
Using catalysts in chemical reactions can increase their speed and selectivity, leading to significant energy savings. One section of the course will focus on fuel cell catalysis, and other ideas such as using catalysts in chlorine electrolysis will be introduced to demonstrate how choosing the right counter reaction can result in energy efficiency. The topic of water splitting to obtain hydrogen will be covered later in the course.
We will examine the use of different materials in energy-related devices and how their electronic and ionic properties affect their performance.

Batteries play a crucial role in electromobility by efficiently storing and releasing electrical energy. One part of the course will cover Li-ion batteries, starting with an overview of their fundamentals and the most common cell types. In addition to discussing the characteristics of typical Li-ion electrode materials and electrolytes, the course will show how key performance characteristics such as energy density, power density, and lifespan are influenced by the cell chemistry. The course will also introduce concepts for the next generation of batteries, such as all-solid-state batteries.

Intended Learning Outcomes:
Upon successful completion of this course, students will be able to:
1. Understand and Explain Key Concepts in Electrochemistry:
o Remember and describe the fundamental principles of electrochemistry, including thermodynamics, kinetics, Pourbaix diagrams, and the Butler-Volmer equation.
o Explain the significance of electrochemical processes in energy conversion and storage technologies.
2. Analyze Electrochemical Systems:
o Interpret Pourbaix diagrams to determine the stability of materials in various pH and potential conditions.
o Apply the Butler-Volmer equation to analyze the kinetics of electrochemical reactions in different energy systems.
o Evaluate the thermodynamic feasibility of electrochemical reactions in sustainable energy applications.
3. Comprehend and Apply Battery Fundamentals:
o Understand the working principles of batteries, including charge/discharge processes, energy density, and power density.
o Differentiate between various battery types (e.g., lithium-ion, sodium-ion, solid-state, flow batteries) based on their materials, design, and application potential.
o Apply knowledge of battery chemistry to assess the performance and suitability of different battery types for specific sustainable energy applications.
4. Develop and Evaluate Sustainable Battery Solutions:
o Develop strategies for improving the efficiency, lifespan, and environmental impact of existing battery technologies.
o Critically evaluate the potential of emerging battery materials and technologies for future energy storage solutions.
5. Understand and Analyze Hydrogen Fuel Cells:
o Explain the principles of hydrogen fuel cells, including the role of catalysts, membrane technology, and the overall electrochemical process.
o Analyze the efficiency and challenges associated with hydrogen fuel cells in comparison to other energy conversion technologies.
o Evaluate the environmental and economic implications of hydrogen fuel cell deployment in various sectors.
6. Comprehend and Apply Knowledge of Electrolyzers:
o Understand the operation of electrolyzers, particularly in the context of hydrogen production from renewable energy sources.

7. Integrate Knowledge to Develop Sustainable Energy Solutions:
o Synthesize knowledge from electrochemistry, battery technology, and hydrogen energy systems to propose innovative solutions for sustainable energy storage and conversion.
o Critically evaluate the trade-offs between different energy materials and technologies, considering factors such as cost, scalability, environmental impact, and performance.
These learning outcomes are designed to ensure that students not only grasp the theoretical concepts of sustainable energy materials but also apply and evaluate these concepts in practical, real-world contexts.

Teaching and Learning Methods:
The module consists of a lecture with integrated exercises. The learning content is conveyed through lectures. In the integrated exercises, students work on individual questions and present their solutions.

1) Lectures:
- Purpose: Lectures provide the essential theoretical foundation in sustainable energy materials, covering key topics like basic electrochemistry, battery fundamentals, and hydrogen fuel cells.
- Approach: Interactive and structured with clear explanations, visual aids, and real-world examples, lectures often include brief in-class exercises to reinforce understanding.
- Outcome Alignment: Lectures support learning outcomes related to understanding and explaining core concepts, while integrated exercises help students begin to apply and analyze these ideas.

2) Exercises and Problem-Solving Sessions:
- Purpose: These sessions reinforce lecture material, allowing students to practice problem-solving, apply theory to real-world scenarios, and deepen their understanding.
- Approach: A mix of individual and collaborative exercises, including problem sets, with guidance from instructors to support learning.
- Outcome Alignment: Exercises align with outcomes related to applying, analyzing, and evaluating knowledge, preparing students for advanced tasks in projects and labs.

Media:
1) Presentation Slides:
• Purpose: Presentation slides will be the primary medium for delivering content during lectures. They will be designed to visually complement the spoken content, providing clear and concise explanations of key concepts, diagrams, equations, and real-world examples.
• Usage: Slides will be used to illustrate complex ideas in electrochemistry, battery technology, and hydrogen systems, helping students to follow along and understand the material more effectively. Key points, equations (e.g., Butler-Volmer equation), and visual aids (e.g., Pourbaix diagrams) will be highlighted to enhance comprehension.
• Accessibility: All slides will be made available to students before or after the lectures via the course’s online platform, allowing for review and study at their own pace.
2) Online Learning Platform:

• Purpose: The online learning platform (e.g., Moodle, Blackboard) will serve as the central hub for course materials, communications, and assessments. It will facilitate a blended learning approach, integrating various media forms into a cohesive learning experience.
• Usage: The platform will host lecture slides, videos, reading materials, quizzes, and assignments. It will also be used for discussion forums where students can ask questions and engage in peer learning. This platform supports continuous access to resources and enables students to manage their learning effectively.
• Interactivity: Features such as quizzes, polls, and discussion boards will allow students to interact with the material and with each other, enhancing engagement and reinforcing learning.
3) Textbooks and Research Articles:
• Purpose: Textbooks and scholarly articles provide in-depth coverage of theoretical concepts and the latest research developments in the field. These resources are essential for supporting lecture content and offering additional perspectives on topics covered in the course.
• Usage: Core textbooks will be recommended for fundamental concepts, such as basic electrochemistry and battery technology. Research articles will be assigned to provide insights into recent advancements and emerging trends in sustainable energy materials. These readings will complement lecture content and form the basis for exercises and discussions.
• Depth: By engaging with these texts, students will deepen their understanding of the material and develop critical thinking skills, particularly in evaluating new research and technological developments.

Reading List:
Handbook of fuel cells, Wolf Vielstich, Hubert A. Gasteiger, Arnold Lamm, 2010
Electrochemical Systems, Karen Thomas-Alyea, John E. Newman, 2021

Responsible for Module:
Prof. Marc Ledendecker

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Module Description

CS0138: Energy and Processes Research Lab | Energy and Processes Research Lab [EPL]

Energy and Process Research Lab

Version of module description: Gültig ab summerterm 2025

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 8	**Total Hours:** 240	**Self-study Hours:** 120	**Contact Hours:** 120

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Carrying out approx. 8 experiments on pilot plant and laboratory equipment and describing and evaluating each and evaluation of the experiment with approx. 5 pages each.

Rhythm of the experiments:
- two-week block practical course with approx. eight experiments per group (consisting of approx. three students)

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Technical Thermodynamics and Balancing, Advanced Downstream Processing, Conceptual Design of Fluid Separation, Chemical- & Thermal Process Engineering

Content:
The students are divided into groups and carry out various practical tests on pilot plant and laboratory equipment, recording different parameters of the equipment. The test performance and results are summarized in a protocol by the students.

Components of the respective laboratory services:
- You will be instructed in the use of the respective laboratory equipment and the safety facilities. will be instructed.
- Theoretical principles as well as practical skills for the experiments are discussed.
- Students work in small groups under supervision on various technical experiments, on the following topics

rectification, sample analysis, redox flow batteries and lithium-ion batteries and others.

Intended Learning Outcomes:
After graduation of the practical course, the students are able to independently design, execute, and evaluate research experiments in energy and process engineering, for exampel in reaction engineering or separation science.

Competencies:
- Students learn how to handle chemical and technical experiments and analytical equipment.
- They gain a basic understanding of technical processes and measurement methods
- They can independently describe the advantages and disadvantages of the technologies under consideration.
- They can identify and explain parameters that influence the productivity and effectiveness of the experiments under consideration.

Teaching and Learning Methods:
Students learn how to use technical apparatus and measuring equipment and are instructed and made aware of how to work safely on such equipment and in a pilot plant and laboratory. Preparation and support is provided during the execution of the experiments. Carrying out the measurements and recording and evaluating the data helps students to learn how to work independently in a group and achieve a common goal.

Media:
Practical course script, laboratory equipment

Reading List:
Practical course script

Responsible for Module:
Matthias Gaderer, Patrick Veiltl

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Module Description

CS0147: Energy Efficient Buildings | Energy Efficient Buildings [EEB]

Version of module description: Gültig ab winterterm 2022/23

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 90	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Students demonstrate their knowledge and understanding of the differenct aspects of energy efficient buildings in form of a written examination (90 minutes). Students deliver definitions, describe and outline relevant processes, mechanisms and requirements of energy efficient buildings. Furthermore, students calculate different technical specifications and parameters based on provided practice-oriented examples.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Basics of physics, Basics of energy technology

Content:
The course focuses on the variety of options for implementation and/or enhancement of energy efficiency in new and existing buildings. This includes an introduction to relevant expert knowledge of energy and ressource efficient building materials and construction. In addition, typical measures for the enhancement of energy efficiency in existing buildings will be presented and evaluated concerning ther sustainability. The second part of the module is concerned with renerwable energy based systems for heat and warm water provision of buildings. Specific advantages and disadvantages of the presented technologies will be discussed in regards to building and usage type. In addition to the presentation of individual measures, it will be analyzed how concepts for energy efficient buildings can be include in modern building infrastructure and on living quarter scale.

Intended Learning Outcomes:
"After successful completion of the module, students acquire in-depth understanding of factors determining the energy efficiency of buildings and relevant legal requirements. Students can

evaluate the sustainability of actions to enhance the energy efficiency of (existing) buildings. In addition, students can understand as well as evaluate and explain advantages and disadvantages of systems for heat and warm water provision based on renewable energies in regards to building and usage type.

Students prepare short, practice-oriented tasks as homework in a project team (group work). Thereby, they acquire the ability to view and assess information within a limited period of time and solve practice-oriented questions. The edited information and results are passed on to the other participants accordingly with the focus on sharing results in the form of a written report as well as team work.

Teaching and Learning Methods:
The content is taught in lecturs and presentations. In addition, case studies and exercises will bei discussed. Students should bei encouraged to individual literature study and discussions on the theme.

Media:
PowerPoint, blackboard, videos

Reading List:
Bauer, M., Mösle, P., Schwarz, M. (201.): Green Building: Leitfaden für nachhaltiges Bauen. Springer Vieweg. Daten von Fachagenturen: BINE Informationsdienst, vom Bundesumweltministerium bzw. entsprechenden Landesministerien und anderen internationalen Organisationen.

Responsible for Module:
Prof. Thomas Vienken thomas.vienken@hswt.de

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Module Description

CS0164: Basics of Numerical Methods and Simulation | Basics of Numerical Methods and Simulation [NumS]

Version of module description: Gültig ab summerterm 2025

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 120	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Examination is done in the form of a written test. As an aid the materials (lecture slides, example programs) used during the lecture may be employed. The students show by solving programming tasks that they know the basics of Matlab and are able to employ it to implement numerical methods for solving simple practical problems. They apply these methods to specific technical problems in case studies. In doing so, they also demonstrate their capability to discern which way to solve a problem is appropriate.
Exam duration: 90 minutes

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
Physics, Mathematics

Content:
'- Basics of programming using Matlab/Simulink
- simple numerical methods: Systems of linear equations, numerical integration & differentiation, finding zeros,
- numerical solution of differential equations
- application of methods by using case studies (e.g. mechanical and electric systems)

Intended Learning Outcomes:
After having participated in the module the students understand basic concepts of various numerical methods for solving algebraic and differential equations and are able to create system models using various methods. They can apply these methods to case studies presented in the course methods using self-created programs in Matlab/Simulink. In doing so, they have also

learned to implement different solutions and discern how appropriate to the problem they are.
In simple cases, they are also able to evaluate their results in terms of plausibility and accuracy.
Furthermore, the participants acquire Matlab programming experience.

Teaching and Learning Methods:
The module consists of a lecture with embedded exercises. Contents of the lecture are presented by the lecturer and are deepened by doing exercises in course and homework exercises. Usually the exercises involve programming tasks.

Media:
Presentations, writing on the board, demonstration of programmes/scripts

Reading List:
S. R. Otto & J.P. Denier, An Introduction to Programming and Numerical Methods in MATLAB, Springer, London, 2005
O. Nelles, Nonlinear System Identification, Springer, Berlin, 2010

Responsible for Module:
Prof. Josef Kainz

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Module Description

CS0254: Introduction to Management of Renewable Resources | Introduction to Management of Renewable Resources

Version of module description: Gültig ab summerterm 2024

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 90	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The examination is a written exam (120 minutes). The students demonstrate that, within a limited time and without tools, the economic relationships involved in the use of renewable raw materials have been understood and can be analyzed and further developed in connection with individual company activities. The exam also examines the extent to which the students can characterize the various markets for renewable raw materials and show possible solutions for material and energetic use.

The lecture and exercise "Economics of Renewable Resources" accounts for 65% and the lecture "Markets for Renewable Resources" for 35% of the overall grade.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:

Content:
The lecture is divided into 3 parts. Although these are independent of each other in terms of content, they address different facets of the economy of renewable resources.

1. Lecture Economics of Renewable Resources
Introduction to the basics of economics using selected conversion paths based on renewable raw materials, from location decisions to procurement and logistics, production, inter-company connections to external reporting.

2. Lecture Markets of Renewable Resources

Presentation of different markets for renewable raw materials. These are divided into material use (bio-lubricants, materials, base chemicals and fine chemicals) and energetic use (heat, electricity and mobility).

3. Exercise Economics of Renewable Resources
The content of the lecture is to analyze and critically evaluate the economics of renewable resources using case studies, so that the participants can independently develop the content further based on the content of the lecture.

Intended Learning Outcomes:
After completion of the module, the students can apply the economic principles of using renewable raw materials in a differentiated manner and analyze and evaluate the economics using case studies from individual companies. Furthermore, they are able to critically assess the business and market relationships in the utilization of renewable raw materials and to include current developments. In addition, the students can assess and compare the different forms of marketing and market sizes of renewable raw materials.

Teaching and Learning Methods:
Lecture; discussions; case studies
With the help of the lectures and exercises, all sub-areas of the module are presented. With the help of this method, the extensive volume of material can be communicated in the best way. In the discussions, the students learn to integrate different perspectives and to correctly classify and critically assess the module content.

Media:
Presentations, script, case studies

Reading List:
Wacker, H., Blank, J. E.: Ressourcenökonomie, Bd. 2 Einführung in die Theorie erschöpfbarer natürlicher Ressourcen, München, Oldenbourg Verlag, 1999.;
KALTSCHMITT, M. und H. HARTMANN (Hrsg.): Energie aus Biomasse. Grundlagen, Techniken und Verfahren. Springer Berlin, 2009;
Vahs, D., Schäfer-Kunz, J.: Einführung in die Betriebswirtschaftslehre. Schäffer-Poeschel Verlag Stuttgart. 2012

Responsible for Module:
Prof. Hubert Röder

Courses (Type of course, Weekly hours per semester), Instructor:
Overview Markets of Renewable Resources (Lecture) (Vorlesung, 1,5 SWS)
Decker T

Management of Renewable Resources (Exercise) (Übung, 1 SWS)
Röder H

Management of Renewable Resources (Lecture) (Vorlesung, 1,5 SWS)
Röder H [L], Pokholkova M, Röder H
For further information in this module, please click campus.tum.de or here.

Module Description

CS0263: Geothermal Energy Systems | Geothermal Energy Systems [GeoE]

Potentials of geothermal energy supply

Version of module description: Gültig ab winterterm 2022/23

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 90	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Students demonstrate their knowledge and understanding of geothermal systems and their potential for energy supply in form of a written examination (90 minutes). Students deliver definitions, describe and outline relevant processes for the geothermal energy supply. Furthermore, students calculate different technical specifications and parameters based on provided practice-oriented examples.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Successful completion of the module "Basics in engineering" and "Introduction to Energy conversion and Energy economy". Knowledge and interest in Geology and Physics are valuable.

Content:
The course focuses on the variety of options for geothermal energy supply. This includes an introduction to relevant geological expert knowledge such as formation of the earth, earth's structure, geothermal heat sources, the rock-cycle as well as mechanism of subsurface heat transport. After an introduction to deep geothermal exploration (drilling, drilling technology and related risks) the focus of the course is placed on shallow geothermal energy and use of ground-coupled heat pump systems.

This includes the design and working principle of a heat pump system and its integration in technical building equipment as well as the analysis of their ecological and economic sustainable operation on living quarter scale. The analysis is also done with regards to existing technical guidelines as well as legal boundary conditions. Practice-oriented tasks will be used to demonstrate and critically evaluate the basic planning steps of heat pump systems and obtaining the relevant parameters. Existing and innovative geothermal exploration concepts will be analyzed and discussed against this background.

Intended Learning Outcomes:
After successful completion of the module, students acquire in-depth understanding of geothermal energy systems including relevant geological and hydrogeological processes. Students can evaluate the ecological as well as economic sustainability of geothermal heat source systems. They can test plausibility of dimensioning ground-coupled heat pump systems and understand, explain and comprehend heat transport processes and regeneration processes within the subsurface.

Students prepare short, practice-oriented tasks as homework in a project team (group work). Thereby, they acquire the ability to view and assess information within a limited period of time and solve practice-oriented questions. The edited information and results are passed on to the other participants accordingly with the focus on sharing results in the form of a written report as well as team work.

Teaching and Learning Methods:
The content is taught in lectures and presentations and strengthened by case studies and exercises. If applicable, the module is complemented by an excursion.

Media:
Lecture, Power Point presentation, blackboard, case examples, topics prepared and presented by participants.

Reading List:
Bayerisches Staatsministerium für Landesentwicklung und Umweltfragen (2005): Oberflächennahe Geothermie.
Bauer, M., Freeden, W., Jacobi, H., Neu, Th. (Hrsg.) (2018): Handbuch Oberflächennahe Geothermie. Springer Spektrum, 1. Auflage.
Stober, I. & Bucher, K. (2014): Geothermal Energy. Springer Spektrum, 1st edition.
Hölting, B., Coldewey, W.G. (2013): Hydrogeologie. Springer Spektrum, 8. überarbeitete Auflage.
Dassargues, A. (2018): Hydrogeology: Groundwater Science and Engineering, CRC Press, 1st edition.
Grotzinger, T. & Jordan, T. (2017): Press/Siever Allgemeine Geologie. Springer Spektrum, 7. Auflage
Grotzinger, T. & Jordan, T. (2014): Understanding Earth. W.H. Freeman & Company, 7th edition

Responsible for Module:
Prof. Thomas Vienken

Courses (Type of course, Weekly hours per semester), Instructor:
Geothermal Energy Systems (Vorlesung mit integrierten Übungen, 4 SWS)

Vienken T [L], Vienken T
For further information in this module, please click campus.tum.de or here.

Module Description

CS0268: Applied Process Engineering | Applied Process Engineering [APE]

Applied process engineering

Version of module description: Gültig ab summerterm 2023

Module Level: Master	Language: English	Duration: one semester	Frequency: summer semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 120	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The examination is performed in the form of a written examination (60 minutes). The students prove that they can solve arithmetic problems and apply methods of cost estimation and economic feasibility studies of process engineering processes as well as answer questions about optimization and cost reduction in writing.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Apparatus and plant construction, bioprocess engineering, chemical reaction technology, thermal process engineering

Content:
The module teaches the basics that are necessary for estimating costs and assessing the profitability and sustainability of a production process. Various methods of cost estimation are taught, as well as their suitability and accuracy in different project phases. The contents are in particular the following:

- Project/design phases (proof of principle, process development in the laboratory, piloting, demonstration, concept study, basic engineering, detail engineering, construction, commissioning, production, debottlenecking)
- Cost estimation (methods, including the Monte Carlo method, accuracy, process variants, sensitivity analyses, tornado plots)
- Assessment of Sustainability

- Investment versus CMO production
- Site selection and plant size
- permits
- Time plans
- Selected examples from industry
- (Operational) optimization and Lean Six Sigma tools
- Business Case Evaluation (Payback, Discounted Cash Flow, Net Present Value, Sales at Maturity)

Intended Learning Outcomes:
After participating in the module, the students are able to estimate operating and investment costs in the respective design phases for a production plant and to reduce production costs during the operation of a plant.

Teaching and Learning Methods:
In the lecture, the essential basics are presented and worked out. The content learned is applied to concrete practical questions in the exercise. Special software for cost estimation is learned in a computer exercise and sample calculations are carried out. Individual topics are worked on and presented in groups. After participating in the module, the students are able to apply the basics of cost estimation and to evaluate the profitability and sustainability in different project phases.

Media:
Presentations, interactive quizzes, case descriptions, computer exercises with software

Reading List:
Peters, M. S., Timmerhaus, K. D., West, R. E., 2003. Plant Design and Economics for Chemical Engineers. McGraw-Hill Education. ISBN 9780072392661

Vasudevan, P. T., Ulrich, G. D., 2004. Chemical Engineering Process Design and Economics: A Practical Guide. United States: Process Pub.. ISBN 9780970876829

Penney, W. R., Couper, J. R., Fair, PhD, J. R., 2012. Chemical Process Equipment: Selection and Design. Netherlands: Elsevier Science. ISBN 9780123969590

Towler, G., Sinnott R., 2021. Chemical Engineering Design - Principles, Practice and Economics of Plant and Process Design. Elsevier. ISBN 9780128211793

Chmiel, H. Bioprozesstechnik. (2011). Germany: Spektrum Akademischer Verlag. ISBN 9783827424761

Responsible for Module:
Michael Zavrel

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Module Description

CS0295: Principles of Life Cycle Assessment | Principles of Life Cycle Assessment

Version of module description: Gültig ab winterterm 2024/25

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 120	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Written exam (90 minutes): Students have to solve problems from the thematic field of the module. They have to prove their ability to use the right vocabulary, apply their knowledge on principle topics in Life Cycle Analysis and systems thinking and life cycle assessment. Learning aids: pocket calculator.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
none

Content:
The module contains units covering the following topics:
• Principles of life cycle thinking
• LCA following the ISO 14040/14044 and ILCD standards
• Selected Life Cycle Impact Assessment Methods such as for
- Climate Change
- Land use and land use change
- Water use
- Resource use
• Attributional and consequential assessments
• Principles of Multi Criteria Decision Analysis (MCDA)
• Presentation and visualization of results
• Handling of data uncertainty
• Current trends and developments
• Software systems and data bases for material flow analysis and life cycle assessment

• Case study

Intended Learning Outcomes:
The students get an introduction into the principle concepts and tools of life cycle assessment to assess products, services and processes regarding their environmental impacts. Thus, they are able to gain a principle understanding of their underlying material and energy flows and how they impact the environment. With these competencies the development and improvement of systems, products and services can be supported, decision support delivered and communication with stakeholders aided.

Teaching and Learning Methods:
Format: lecture and exercises to introduce the content, to repeat and deepen the understanding as well as practice based on a simple case study.
Teaching / learning methods:
- Media-assisted presentations
- Group work / individual case study
- Computer lab exercises using LCA software systems and Life Cycle Inventory data bases.

Media:
Digital projector, board, flipchart, online contents, case study, computer lab

Reading List:
Recommended reading:
• Curran, M.A. (2015): Life Cycle Assessment Student Handbook, Scrivener Publishing:
• Hauschild, M.Z. & Huijbregts, M.A.J. (2015): Life Cycle Impact Assessment (LCA Compendium - The Complete World of Life Cycle Assessment), Springer.
• Klöpffer, W. & Grahl, B. (2014): Life Cycle Assessment (LCA), Wiley-VCH.
• Recent articles from esp. International Journal of Life Cycle Assessment, Journal of Cleaner Production, Journal of Industrial Ecology, Environmental Science and Technology (to be announced in the lecture)

Responsible for Module:
Prof. Hubert Röder

Courses (Type of course, Weekly hours per semester), Instructor:
Principles of Life Cycle Assessment (Lecture) (Vorlesung, 2 SWS)
Röder H [L], Füchsl S, Röder H

Principles of Life Cycle Assessment (Exercise) (Übung, 2 SWS)
Röder H [L], Füchsl S, Röder H
For further information in this module, please click campus.tum.de or here.

Module Description

CS0308: Carbon Capture, Storage, and Utilization | Carbon Capture, Storage, and Utilization

Version of module description: Gültig ab summerterm 2025

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 90	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The basics of carbon capture, storage and use will be tested in an oral examination (25 minutes). The students demonstrate that they have understood the technology of CO2 separation plants and that they are able to carry out calculations on the design, energy yield, and economic efficiency of such plants. They also show that they have understood technologies for sequestration and short-term storage of CO2 and are able to balance and evaluate chemical processes that use CO2 as a raw material.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
Thermodynamics of Mixtures, Fluid Separation processes

Content:
Physical and chemical properties of CO2 and mixtures containing CO2; basics of sorption processes; processes for CO2 separation from natural gas and flue gas; processes for direct air capture; processes for CO2 sequestration; CO2 as raw material for C1-Chemistry, reverse-water-gas-shift; CO2 as substrate for biotechnological processes; CO2 as chemical product

Intended Learning Outcomes:
After attending the module, the students will be able to characterise different types of CO2 capture systems for both industrial gas streams and the atmosphere. They recognise and understand the plants from a technical and energy point of view. The students understand the challenges involved in sequestering and storing CO2, as well as in converting it into valuable chemical products and fuels. They are able to evaluate the plants along the CO2 value chain from an economic and ecological point of view.

Teaching and Learning Methods:
The module consists of a lecture and an exercise. The contents of the lectures are primarily conveyed by the lecturers through presentations. Thereby, the students should get a well-founded insight into the topic. The exercises include technical calculations for the process units presented in the lecture on the one hand, and the various aspects of the sustainability calculation of CO2 value chains on the other. In the excercise, both classroom sessions and self-study are used. Therby, students are motivated to research the current state of the art in this highly topical field of technology.

Media:
Scriptum, handouts, scientific and technical literature

Reading List:
"- Wilcox, Jennifer. Carbon capture. Springer Science & Business Media, 2012;
- Aresta, Michele, ed. Carbon dioxide as chemical feedstock. Vol. 416. Weinheim: Wiley-VCH, 2010.
- Fischedick, Manfred, Klaus Görner, and Margit Thomeczek, eds. CO2: Abtrennung, Speicherung, Nutzung: Ganzheitliche Bewertung im Bereich von Energiewirtschaft und Industrie. Springer-Verlag, 2015.;
"

Responsible for Module:
Jakob Burger burger@tum.de

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Module Description

CS0309: Principles of Economics | Principles of Economics

Version of module description: Gültig ab summerterm 2025

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 90	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
In the exam (written, 120 minutes) students should demonstrate their ability to adequately interpret the economic concepts and apply the methods worked on in class. By means of multiple-choice-questions, which are either embedded in a context/case/scenario or require prior computation, students' capacity to apply the learned solution strategies to new settings and draw correct economic implications is assessed. A non-programmable calculator is allowed.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:

Content:
This module offers an introduction to fundamental economic concepts, including an overview of the key institutions of capitalism such as private property, firms, and markets. It explores economic history and examines how technological change serves as a catalyst for economic growth. The module also covers welfare economics, the dynamics of price-taking and competitive markets, and identifies market power and externalities as sources of market failure. Additionally, it discusses regulation and government interventions in markets, with a focus on specific markets such as energy markets and carbon pricing. The decision-making processes of individual economic agents are also analyzed.

Intended Learning Outcomes:
After attending this module, students will understand important economic concepts like tradeoffs, welfare, and wealth. They understand how consumers and producers are modeled and how resulting competitive markets work. In addition, they can describe different market structures and conditions under which inefficient market outcomes for society and the environment occur.

Students will be equipped with the necessary tools to analyze the effectiveness of policy interventions and to determine their impact on consumers and firms.

Teaching and Learning Methods:
An interactive lecture introduces essential economic concepts and theories and illustrates them with the help of topical empirical examples. Classroom experiments complement the classic bird-eye's perspective by nudging students to put themselves in the positition of particular economic players, thereby requiring them to actively reflect the concepts introduced. Online surveys at the end of each chapter enable students to select which topics they would like to intensify in subsequent classes. In the exercises, students practice, on specific problems and examples, the mathematical techniques needed to develop a deeper understanding of the economic concepts. In self-study students use a textbook to repeat the concepts introduced in class and apply them to additional examples.

Media:
Textbook, slides, exercise sheets, classroom experiments, online surveys

Reading List:
Robert S. Pindyck and David L. Rubinfeld, Microeconomics, 8th Edition, Pearson, 2013 (ISBN 13: 978-0-13-285712-3). AND Robert S. Pindyck und David L. Rubinfeld, Mikroökonomie, 8. Aufl., Pearson Studium, 2013 (ISBN-13: 978-3868941678).

Responsible for Module:
Sebastian J. Goerg Andreas Pondorfer

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Module Description

CS0313: Biogas Technology | Biogas Technology [BiGA]

Version of module description: Gültig ab winterterm 2024/25

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 100	**Contact Hours:** 50

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Students take a written examination (90 minutes) to demonstrate their knowledge of microbial breakdown processes in the biogas process, as well as their ability to assess influencing factors. They also demonstrate their knowledge of various technologies for using biogas and can explain their respective advantages and disadvantages. Additionally, they demonstrate that they have understood the legal and economic framework conditions of biogas technology and are able to translate these to case examples. Students also show that they can develop basic concepts of biogas plants.They will answer questions on the topic in their own wording and explain case examples or work out calculations. Multiple-choice questions are also possible.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Required: basic knowledge in biology, especially microbiology, as well as general and organic chemistry, mathematics, physics and thermodynamics of cycles; of advantage: knowledge in agriculture and agricultural engineering

Content:
Microbiology of biogas processing, anaerobic substrate breakdown, factors influencing the fermentation process, process management strategies, biogas storage and purification; biogas recovery (e.g. use of a motor for power generation with or without the use of heat or feeding into the gas grid); legal-economic framework conditions; sustainability issues; competition for raw material and acceptance of biogas plants; aspects of biogas plant design.

Intended Learning Outcomes:
After successful completion of the module, students are able to develop concepts for biogas generation and recovery in a specific context. Students are aware of microbial breakdown

processes in biogas plants and can differentiate between various influencing factors. They are also aware of various processes for the use of biogas and understand their advantages and disadvantages. Students recognize the meaning of biogas technology for sustainable energy supply. Students have a good knowledge of legal and economic framework conditions in the field of biogas generation and they are able to conceptualize basic biogas plants.

Teaching and Learning Methods:
Lectures given as presentations, with the help of a blackboard and interactive elements, in particular group work on case examples; optional: excursion to a biogas plant to deepen acquired knowledge in a real-life setting

Media:
PowerPoint presentation, slide notes, exercise sheets

Reading List:
D. Deublein, A. Steinhauser, Biogas from Waste and Renewable Resources - An Introduction, Wiley-VCH, 2010, ISBN-13: 978-3-527-32798-0, ISBN-10: 3-527-32798-3

Responsible for Module:
Dr. Doris Schieder

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Module Description

CS0314: Sustainable Fibre Technologies | Sustainable Fibre Technologies [SFT/P]

Sustainable fibre technology

Version of module description: Gültig ab summerterm 2025

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 90	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Assessment takes the form of a written examination (120 minutes).
The students can demonstrate their ability to distinguish the chemo-physical, structrual and mechanical differences between various natural fibres, processed biopolymer fibre and regenerate fibres. They can describe basic sustainable fibre process technologies and fibre applications, and can answer questions regarding sustainable fiber spinning technologies.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Organic Chemistry, Polymer Chemistry, Chemical- & Thermal Process Engineering, Mechanical Processing of biogenic Materials,
Biogenic Polymers

Content:
The module provides an overview of fundamental production methods for biogenic and biodegradable fiber and their processing, covering the fibre structures and mechanical properties. The module introduces various fiber spinning technologies and guides on selecting appropriate methods for converting different bio-based polymers into fibers. The course also explores the applications of natural and biodegradable polymers in various industries, including textiles, packaging, and composites. Furthermore, it briefly covers material characterization methods for natural and biogenic fibers and their fibre composites.

Intended Learning Outcomes:
After completing the module, students will be able to evaluate the properties and applications of various natural fibers, synthetic and regenerated fibers made from biodegradable polymers. They will be able to explain the most important fibre spinning technologies and the most important characterization methods for fibres.

Teaching and Learning Methods:
The module consists of lecture and exercise.
The content of the module is conveyed during the lecture by speech and presentations. The students are encouraged to engage actively with the topics by integrating various self-search tasks and comprehension questions.
In the exercises, which take place in alternation with the lecture, serve for a stronger comprehension of the teaching contents.

Media:
Presentations, scripts, exercises

Reading List:
- Dieter Veit; 2022. Fibers: history, production, properties, market. Weinheim: Springer. ISBN 978-3-031-15308-2, ISBN 978-3-031-15309-9 (eBook).
- Vijay Kumar Thakur and Manju Kumari Thakur, 2015. Handbook of sustainable polymers: processing and applications. Taylor & Francis Group.
- Sabu Thomas, Ajitha AR, Cintil Jose Chirayil, Bejoy Thomas, 2023 Handbook of biopolymers. Springer. ISBN 978-981-19-0709-8, ISBN 978-981-19-0710-4 (eBook)
- David Plackett, 2011, Biopolymers – New Materials for Sustainable Films and Coatings, John Wiley and Sons. ISBN 9780470683415

Responsible for Module:
Wenwen Fang

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Research Internship (max. 10 ECTS) | Research Internship (max. 10 ECTS)

Module Description

CS0294: Research Internship Master 5 ECTS | Research Internship Master 5 ECTS

Version of module description: Gültig ab summerterm 2024

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** winter/summer semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 30	**Contact Hours:** 120

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The examination consists of a graded internship report (15-30 pages, depending on the topic) and/or an Presentaion (20-30 minutes, depending on the topic) on the contents and contents of the internship results containing at least an overview of the state of knowledge on the project topic as well as the presentation of the working methods used and a presentation of the results with interpretation. In an overall grade, the quality of the familiarisation with the topic, the experimental work, the interpretation of the results and the written elaboration and/or presentation are evaluated.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Background knowledge of the respective focus to which the project topics of the research internships are assigned. In this case, having a background in Python or SuperPro Designer and experience in the laboratory is often recommended.

Content:
Research-related work at the chairs and working groups of the TUM Campus Straubing. The students receive tasks from the research area of the supervising examiner, which they work on under guidance in the form of projects. The subject areas must be able to be assigned to the technical content of the study program. The students plan the project work largely independently under the guidance of the supervisors. The project work consists of 120 working hours, fixed in consultation with the supervisors, usually as a block internship on consecutive weeks, which can be deviated from in consultation. The project work is documented and evaluated in the form of an

internship report. In addition, a supplementary presentation of the work progress takes place. The project work can also be done with external institutions, such as companies.

Intended Learning Outcomes:
After participation in the module, students understand the principles of approach to (research)projects in addition to the subject-specific knowledge and working methods taught in the research internship projects, the planning of project work and the critical evaluation of the project results and can apply them to new project tasks. Furthermore, they are able to document, interpret and summarise project work and results in written form.

Teaching and Learning Methods:
Depending on the focus and topic, for example, experiments in laboratories, guided or independent literature and data research, concept studies, simulations, methods for project and experimental design or test evaluation

Media:
Depending on the focus and topic, e.g., experimental equipment (laboratory), databases, libraries, specialized software, programming software, simulation software, project and experimental design software

Reading List:
technical literature;
Davies, M. B. (2007): Doing a successful research project. Using qualitative or quantitative methods. Basingstoke: Palgrave

Responsible for Module:
Zollfrank, Cordt; Prof. Dr. rer. silv.

Courses (Type of course, Weekly hours per semester), Instructor:
Kleines Forschungspraktikum Master CBT (Niederholtmeyer) (Forschungspraktikum, 4 SWS)
Banlaki I, Crean E, Gaizauskaite A, Kalkowski J, Li Y, Niederholtmeyer H

Research Internship Master 5 ECTS (Praktikum, 5 SWS)
Blombach B, Glawischnig E, Hädrich M, Vital S

Research Internship Master 5 ECTS (CTV) (Forschungspraktikum, 5 SWS)
Burger J [L], Elfaitory H, Groh D, Ibanez M, Muraleedharan A, Rosen N, Staudt J, Winklbauer L, Wolf A

Research Internship Master 5 ECTS (Forschungspraktikum, 5 SWS)
Costa Riquelme R [L], Costa Riquelme R

Reseach Internship Master 5 ECTS (RES) (Praktikum, 5 SWS)
Gaderer M [L], Huber B, Putra L

Research Internship Master 5 ECTS (Forschungspraktikum, 5 SWS)
Ledendecker M [L], Bhuyan P, Lim S, Pfeifer P, Sanyal S, Vilalba Fortunato G

Research Internship Master 5 ECTS (Forschungspraktikum, 5 SWS)
Sieber V [L], Abbas Nia A, Al-Shameri A, Arana Pena S, Dsouza Z, Fornoni E, Friedrichs J, Fuchs A, Giustino A, Grundheber J, Hofer N, Hörnschemeyer K, Hupfeld E, Kampl L, Köllen T, Liu Y, Malubhoy Z, Marosevic M, Matena F, Mayer M, Ostertag T, Raga Carbajal E, Rau M, Romeis D, Rühmann B, Scheerer J, Schieder D, Schulz M, Sieber V, Siebert D, Skopp A

Research Internship Master 5 ECTS (Forschungspraktikum, 5 SWS)
Zavrel M [L], Beerhalter D, Borger J, Dsouza V, Geisler N, Marino Jara J, Oktay I, Stegemeyer U, van der Walt H, Zavrel M
For further information in this module, please click campus.tum.de or here.

Module Description

CS0297: Research Internship Master 10 ECTS | Research Internship Master 10 ECTS

Version of module description: Gültig ab summerterm 2024

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** winter/summer semester
Credits:* 10	**Total Hours:** 300	**Self-study Hours:** 60	**Contact Hours:** 240

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The examination consists of a graded internship report (15-30 pages, depending on the topic) and/or an Presentaion (20-30 minutes, depending on the topic) on the contents and contents of the internship results containing at least an overview of the state of knowledge on the project topic as well as the presentation of the working methods used and a presentation of the results with interpretation. In an overall grade, the quality of the familiarisation with the topic, the experimental work, the interpretation of the results and the written elaboration and/or presentation are evaluated.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Background knowledge of the respective focus to which the project topics of the research internships are assigned. In this case, having a background in Python or SuperPro Designer and experience in the laboratory is often recommended.

Content:
Research-related work at the chairs and working groups of the TUM Campus Straubing. The students receive tasks from the research area of the supervising examiner, which they work on under guidance in the form of projects. The subject areas must be able to be assigned to the technical content of the study program. The students plan the project work largely independently under the guidance of the supervisors. The project work consists of 240 working hours, fixed in consultation with the supervisors, usually as a block internship on consecutive weeks, which can be deviated from in consultation. The project work is documented and evaluated in the form of an internship report. In addition, a supplementary presentation of the work progress takes place. The project work can also be done with external institutions, such as companies.

Intended Learning Outcomes:
After participation in the module, students understand the principles of approach to (research)projects in addition to the subject-specific knowledge and working methods taught in the research internship projects, the planning of project work and the critical evaluation of the project results and can apply them to new project tasks. Furthermore, they are able to document, interpret and summarise project work and results in written form.

Teaching and Learning Methods:
Depending on the focus and topic, for example, experiments in laboratories, guided or independent literature and data research, concept studies, simulations, methods for project and experimental design or test evaluation

Media:
Depending on the focus and topic, e.g., experimental equipment (laboratory), databases, libraries, specialized software, programming software, simulation software, project and experimental design software

Reading List:
technical literature;
Davies, M. B. (2007): Doing a successful research project. Using qualitative or quantitative methods. Basingstoke: Palgrave

Responsible for Module:
Zollfrank, Cordt; Prof. Dr. rer. silv.

Courses (Type of course, Weekly hours per semester), Instructor:
Research Internship Master 10 ECTS (Forschungspraktikum, 10 SWS)
Banlaki I, Crean E, Gaizauskaite A, Kalkowski J, Li Y, Niederholtmeyer H

Research Internship Master 10 ECTS (CTV) (Forschungspraktikum, 10 SWS)
Burger J [L], Elfaitory H, Groh D, Ibanez M, Muraleedharan A, Rosen N, Staudt J, Winklbauer L, Wolf A

Research Internship Master 10 ECTS (RES) (Praktikum, 10 SWS)
Gaderer M [L], Huber B, Putra L

Research Internship Master 10 ECTS (Sieber) (Forschungspraktikum, 10 SWS)
Sieber V [L], Abbas Nia A, Al-Shameri A, Arana Pena S, Dsouza Z, Fornoni E, Friedrichs J, Fuchs A, Giustino A, Grundheber J, Hofer N, Hörnschemeyer K, Hupfeld E, Kampl L, Köllen T, Liu Y, Malubhoy Z, Marosevic M, Matena F, Mayer M, Ostertag T, Raga Carbajal E, Romeis D, Rühmann B, Scheerer J, Schulz M, Sieber V, Siebert D, Skopp A
For further information in this module, please click campus.tum.de or here.

Interdisciplinary Electives | Allgemeinbildende/Fachübergreifende Wahlmodule

Module Description

CS0258: Renewable Resources in Communication and Instructional Design | Renewable Resources in Communication and Instructional Design

Version of module description: Gültig ab summerterm 2025

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 120	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Over the course of the semester, students are expected to prepare presentations, participate in role plays and work on cases in groups with video analyses (ungraded). The graded examination is completed in two parts. The first part is a graded course (presentation: 20 minutes) in grammar schools and other secondary schools, in which the acquired didactic skills are to be applied (80 % of the grade). The second part of the examination consists of a written report (approx. 10 pages) on the course held at the grammar school (20 % of the grade).

Repeat Examination:
Next semester

(Recommended) Prerequisites:
none

Content:
The basics of communication and didactics, communication methodology, communication rules and their application in everyday working life as well as goal-orientated dialogue management are taught. In addition, expression and language, presentation of the course, presentation of the contents and their practical teaching, the organisation of teaching units at the schools involved, the characterisation of teaching requirements and public relations issues are covered.

Intended Learning Outcomes:
After completing the module, students will be able to analyse basic counselling and communication models and assign the underlying theory to the models accordingly.
Furthermore, students will be able to apply counselling and communication models using case studies.
In addition, they can review their own basic attitude and reflect on their own counselling and communication behaviour. Students can formulate and define learning objectives appropriate to the respective target group and the content to be taught.
They can organise a teaching unit in a meaningful sequence according to the learning objectives and can select appropriate teaching methods to suit the objectives. They can design and implement a curriculum for their teaching unit. Furthermore, students will be able to explain their content-related topics in a binding manner and relate them to the fields of work of the TUM Campus Straubing, analyse the content-related needs of the school and plan the scope of teaching, and will be able to coordinate press and public relations work with content and intentions from the field of renewable resources.

Teaching and Learning Methods:
In addition to the lecture, exercises, role plays, case studies, excursions and video analyses of individual and group presentations will be carried out. There will also be a teaching rehearsal in front of a class at a grammar school in the region.

Media:
Presentations, script, videos, exercise sheets, flipchart, Powerpoint, illustrative objects (renewable raw materials), case descriptions, blackboard

Reading List:
Philipps, E. & Robles, R. (2023). Foundations of Educational Technology: Learning and Instructional Design, Vol 1. Middlesex: Kruger Brentt Publisher.
Philipps, E. & Robles, R. (2024). Foundations of Educational Technology: Learning and Instructional Design, Vol 2. Middlesex: Kruger Brentt Publisher.
McDonald, J.K. & West, R. (2021). Design for Learning: Principles, Processes, & Praxis. Provo: Brigham Young University.
Littlejohn, S.W., Foss, K.A. & Oetzel, J.G. (2021). Theories of Human Communication. Longrove: Waveland Press.
McQuail, D. & Deuze, M. (2020). Media and Mass Communication Theory. London: SAGE Publications Ltd.
Griffin, E., Ledbetter, A. & Sparks, G. (2022). A First Look at Communication Theory. London: McGraw-Hill Education.

Responsible for Module:
Claudia Martin

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Alphabetical Index

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