Module handbook

REM M.Sc. Renewable Energy Engineering and Management

Academic year 2022/2023

State of 16.08.2022

Table of contents

Module handbook
Master of Science
Renewable Energy Engineering and Management

1. Introductory comments

According to § 4 of the examination regulation of the MSc Renewable Energy Engineering and Management a module handbook lists the module contents. The module handbook refers to the academic year and gives information about the time schedule, type and scope of the module related courses and examinations.

The MSc Renewable Energy Engineering and Management is a two-year course. In the first part the time schedule for the students in their respective semester (first or third semester, second or fourth semester) is given. In the second part the module descriptions (listed accordingly to the time schedule given in the first part) inform about the contents and course prerequisites of the individual modules.

The module handbook is available on the website of the MSc Renewable Energy Engineering and Management (www.rem.uni-freiburg.de). Thus students have access to the module handbook before and during their studies.

2. Schedule

<table>
<tr><td></td><td colspan="26">Winter term 2022/23 First Semester</td><td></td></tr>
<tr><td></td><td colspan="4">October</td><td colspan="5">November</td><td colspan="4">December</td><td colspan="5">January</td><td colspan="4">February</td><td colspan="4">March</td><td></td></tr>
<tr><td>CW</td><td></td><td></td><td></td><td>43</td><td>44</td><td>45</td><td>46</td><td>47</td><td>48</td><td>49</td><td>50</td><td>51</td><td>52</td><td>53</td><td>01</td><td>02</td><td>03</td><td>04</td><td>05</td><td>06</td><td>07</td><td>08</td><td>09</td><td>10</td><td>11</td><td>12</td><td>CW</td></tr>
<tr><td></td><td colspan="3">14.10.</td><td colspan="9">17.10 - 16.12.</td><td colspan="2">- 7.01.</td><td colspan="3">09.01 - 27.01.</td><td colspan="3">30.01. - 17.02.</td><td colspan="3">20.02. -10.03.</td><td colspan="3"></td><td></td></tr>
<tr><td rowspan="5">REM (1st Sem.)</td><td colspan="3" rowspan="4">Introductory day</td><td colspan="7">Module
Energy & Sustainable Development</td><td rowspan="2"></td><td colspan="3" rowspan="5">**Christmas Break**</td><td colspan="6" rowspan="3">Module
Natural Resources and Conversion Technologies</td><td colspan="3" rowspan="3">Module
Climate & Energy Policy</td><td colspan="3" rowspan="4"></td><td rowspan="5">REM (1st Sem.)</td></tr>
<tr><td colspan="7">**Pauliuk**</td></tr>
<tr><td colspan="8">Module
Scientific Framework for REM</td></tr>
<tr><td colspan="8">**von Detten**</td><td colspan="6">**Pauliuk**</td><td colspan="3">**Ragwitz**</td></tr>
<tr><td colspan="11"></td><td colspan="12"></td></tr>
</table>

Summer term 2023

	April	April / May	May / June	June	June / July	July / August	August	
CW	16, 17, 18	19, 20, 21	22	23, 24, 25	26, 27, 28	29, 30, 31	32, 33, 34, …	CW
	17.04. - 05.05.	08.05. - 26.05.	29.05. -02.06	05.06. - 23.06.	26.06. - 14.07.	17.07. - 04.08.		
REM (2nd Sem.)	Module **Energy Systems Operations**	Module **Introduction to Business Manage-ment**	**Pentecoast Break**	Module **Research Skills and Ethics for Sustainable Development**	Module **Elective Hydropower** **Solar Thermal Energy 1** **Elective Global Sustainability Transformations in Local Contexts** **Leadership and Social Entrepreneurship**	Module **Elective Bioenergy** **Elective Wind energy**	Module **Internship**	REM (2nd Sem.)
	Weidlich	**von Detten**		**Zengerling**	**Weiler** **Platzer** **Zengerling** **Schanz**	**Paczkowski** **Schindler**	**Pauliuk**	
	Energy in Buildings: energy demand and building physics – Henning (whole semester)							

Colour code	Cross sectional topic “Energy Conversion” 10-20 ECTS
Colour code	Elective Track Renewable Energy Management and Planning (REPM) 15-25 ECTS
Colour code	Elective Track Energy Systems Technology (EST) 15-25 ECTS

	Winter term 2022/23 Third Semester																										
	October					November			December					January				February			March						
CW				42	43	44	45	46	47	48	49	50	51	52	01	02	03	04	05	06	07	08	09	10	11	12	CW

REM (3rd Sem.)	17.10. -	07.11. - 25.11.	28.11. – 16.12.			09.01–27.01.	30.01. – 17.02.	20.02. – 10.03.		REM (3rd Sem.)
	Module	Modules Elective Tracks	Modules Elective Tracks		Christmas Break	Modules Elective Tracks	Modules Elective Tracks	Module Elective Tracks		
	Optimization and Forecasting for Energy Systems **Complex Networks** **Energy System Modeling with Python** **Smart Grids** **Modelling and System Identification** **Energy in Buildings: components + systems for energy supply** **Numerical optimization** **Energy Storage**					**Weidlich** **Schäfer** **Weidlich** **Wittwer** **Diehl** **Henning** **Diehl** **Schossig**				
	Internship	**Photovoltaics 1***				**Photovoltaics 2*** **Solar Thermal Energy 2****				
		Managing RE Projects – Case Studies	**Landscape, Nature Protection, Landuse Conflicts** **Environmental Economics**			**Life Cycle Management** **Environmental and Energy Transition Law** **Technology Assessment – Theory/Practice**	**Regulation and Assessment of the Systemic Aspects of the Energy Transition**	**Industrial Ecology Thesis Projekt** **Introduction to Sustainability Transitions**		
	Pauliuk	**Henning*** **Ruppert-Winkel**	**Henning*** **Koch** **Baumgärtner**			**Henning*** **Pauliuk** **Zengerling** **Späth**	**Platzer**** **Bauknecht**	**Pauliuk** **Bauknecht**		

3. Module descriptions

3.1. Winter term 2022/2023 – first semester

- **Energy and Sustainable Development**
- **Scientific Framework for REM**
- **Natural resources and Conversion Technologies**
- **Climate and Energy Policy**

3.2. Winter term 2022/23 – third semester

- **Internship**
- **Elective Track "Energy Systems Technology"**
  - ❖ **Optimization and Forecasting for Energy Systems**
  - ❖ **Complex Networks**
  - ❖ **Energy System Modeling with Python**
  - ❖ **Smart Grids**
  - ❖ **Modelling and System Identification**
  - ❖ **Energy in Buildings: components and systems for energy supply**
  - ❖ **Numerical optimization**
  - ❖ **Energy Storage**
- **Elective Track "Renewable Energy Planning and Management"**
  - ❖ **Managing RE Projects – Case Studies**
  - ❖ **Landscape, Nature Protection, Landuse conflicts**
  - ❖ **Life Cycle Management**
  - ❖ **Environmental and Energy Transition Law**
  - ❖ **Technology Assessment – Theory and Practice**
  - ❖ **Regulation and Assessment of the Systemic Aspects of the Energy Transition**

- **Introduction to Sustainability Transitions**
- **Industrial Ecology Thesis Projekt**

- **Cross sectional topic “Energy Conversion”**
  - **Photovoltaics 1**
  - **Photovoltaics 2**
  - **Solar Thermal Energy 2**

3.3. Summer term 2023 – second semester

- **Energy Systems Operations**
- **Introduction to Business Management**
- **Society and Economy**
- **Research Skills and Ethics of Sustainable Development**
- **Elective Hydropower**
- **Elective Solar Thermal Energy 1**
- **Elective Global Sustainability Transformations in Local Contexts**
- **Elective Leadership and Social Entrepreurship**
- **Elective Bioenergy**
- **Elective Wind Energy**
- **Energy in Buildings: energy demand and building physics**
- **Internship**

<table>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses
----</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
93110</td><td colspan="2">Module name
Energy and sustainable development</td><td>Semester/return
1st Sem. / annual</td></tr>
<tr><td>Workload/presence
5 ECTS-P (150h/60h)</td><td>Prerequisite module(s)
---</td><td>Follow-up module(s)</td><td>No. of participants
Max. 75</td></tr>
<tr><td>Teaching form
Lectures, exercises, group work</td><td>Examination form
Term paper (50%), written assignment (50%)</td><td>Start date
17.10.2022</td><td>Location
Tba.</td></tr>
<tr><td colspan="4">Module coordinator: Prof. Dr. Stefan Pauliuk (stefan.pauliuk@indecol.uni-freiburg.de)</td></tr>
<tr><td colspan="4">Additional teaching staff
Prof. Dr. Ernst Ulrich von Weizsäcker, Johan Velez</td></tr>
<tr><td colspan="4">Syllabus
The module is divided into three parts.

In the first part the students become familiar with the state of the art of the energy transition and climate change mitigation as major aspect of sustainable development. Next to a detailed overview of current and expected future renewable energy supply, energy productivity is discussed in detail. Examples of large productivity gains will be shown from a wide range of industrial sectors, transport, buildings, and agriculture. Also, current and future policy options to steer technologies and investments towards a more renewable energy supply will be discussed (Main responsibility: Prof. Dr. Ernst Ulrich von Weizsäcker)

In the second part we study renewable energy from a systems perspective. We present the systems approach to human-environment interactions and introduce the central interdisciplinary concepts of system science. These concepts include socio-ecological systems and the separation of their biophysical and social aspects, boundary objects to describe objects and concepts across disciplines, socioeconomic metabolism and the biophysical structures of society, and industrial ecology and the circular economy. We briefly describe the metabolism of historic societies and discuss its constraints. We then present two main systems approaches to quantify and assess material and energy flows as well as costs associated with renewable energy installations: Material flow analysis and life cycle sustainability assessment. (Main responsibility: Prof. Stefan Pauliuk)

In the third and last part of the course, students are required to select one of the many aspects of and options related to renewable energy supply and to prepare a short scientific piece of not more than 2000 words and max. 3 figures/tables on their selected topic. This homework will be graded. (Main responsibility: students)</td></tr>
</table>

The module is interactive and encourages strong student participation. Lectures, offering a detailed introduction, are complemented by exercises and autonomous group work and panel discussions. On the basis of the acquired knowledge, students prepare concise written summaries of the state of the art of renewable energy technology development and deployment as well as the system-wide consequences and the ethical background of the energy transition.

Learning goals and qualifications

- Detailed knowledge about the state of the art and scientific methods for assessment of renewable energy conversion and use, energy efficiency, energy policy, resource productivity, emerging technologies, and new political frameworks.
- Basic knowledge of quantitative systems theory and quantitative analysis of human-environment systems, basics of material flow analysis and life cycle sustainability assessment
- Soft skills: discussion and scientific writing skills, capacity for team work

Recommended reading

Von Weizsäcker, E., Hargroves K., Smith M.H., Desha C.: ***"Factor Five"*** (Earthscan, London, 2009)

Hertwich et al. (2015). ***Integrated life-cycle assessment of electricity-supply scenarios confirms global environmental benefit of low-carbon technologies.*** PNAS 112(20), 6277-6282.

Note: All reading is provided as pdf on the University’s online learning platform ILIAS.

Course prerequisites

Basic knowledge about energy conversion, use and efficiency as well as renewable energy conversion technologies.

<table>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses
---</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
93950</td><td colspan="2">Module name
Scientific Framework for REM</td><td>Semester/return
1st Sem. / annual</td></tr>
<tr><td>Workload/presence
10 ECTS (300h/100h)</td><td>Prerequisite module(s)
---</td><td>Follow-up module(s)
---</td><td>No. of participants
max. 75</td></tr>
<tr><td>Teaching form
Lectures, tutorials</td><td>Examination form
Written assignment (pass or fail)</td><td>Start date
19.10.2022</td><td>Location
tba</td></tr>
<tr><td colspan="4">Module coordinator: Dr. Roderich von Detten (r.v.detten@ife.uni-freiburg.de)</td></tr>
<tr><td colspan="4">Additional teaching staff: Christoph Bohnert, Dr. Oswald Prucker, Jun-Prof. Cathrin Zengerling</td></tr>
<tr><td colspan="4">Syllabus
This module is designed to harmonize the heterogeneous background knowledge due to the interdisciplinary and internationality nature of the M.Sc. REM course by providing fundamental knowledge about diverse subjects relevant for this course. At the beginning, the current knowledge in physics, chemistry, biology, engineering, politics, economics, business, and law will be tested and recommendations will be given to the student, which lectures with a total workload of 10 ECTS they should take to fill their knowledge gaps
1. Introduction in Physics, Chemistry, Biology and Engineering
In this module, the basics of mechanics, thermodynamics, electro statics and dynamics, as well as optics are discussed in a physics class. An overview over the chemistry (e.g. assembly of elements, chemical bindings, chemical reactions, organic molecules, polymers) and biology (e.g. photosynthesis, cells in a perspective of biomass) is given. An engineering class provides the students with the fundamental knowledge on electricity (e.g. basics of electronics, electric components, Kirchhoff's laws, diodes, three-phase current)
2.Introduction into Politics, Economics, Business and Law
The economics part of the course presents an overview of basic concepts and methods of microeconomics. Main topics include fundamental principles of economics, consumer theory, producer theory, and market equilibrium and efficiency.
Basics of business economics: Financial Management, Accounting, Balance sheet, performance indicators (liquidity, profitability, financial health etc.), Strategic Aspects of Management; Decision Making in organizations (teaching form: cardboard business game)
The law module introduces into fundamentals of law and state theory from an international, multi-level governance and comparative perspective. It presents basics of the legal framework relevant for renewable energies and makes students familiar with key legal primary sources in this context.</td></tr>
<tr><td colspan="4">Learning goals and qualifications
1. Introduction in Physics, Chemistry, Biology, and Engineering
The students acquire basic knowledge in physics and engineering to provide the required prerequisites for advanced technology classes. The students understand the concepts of thermodynamics, mechanics, electro statics and dynamics, and optics as well as the electric engineering, which consists of electrical components, electrical circuits and conduction. The students learn fundamental concepts of chemistry and biology providing a basis for understanding biomass and conversion into bioenergy. This includes the classifications and properties of basic elements of the periodic table and survey the different bonding mechanisms and resulting chemical species, the fundamentals of chemical reactions including stoichiometry with a specific emphasis on reactions relevant to biomass such as acid / base reactions.</td></tr>
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2.Introduction into Politics, Economics, Business and Law

Students acquire adequate understanding of microeconomic theory and they are able to apply this to practical contexts. The economics part builds on the basic concepts in consumer and producer theory. They understand the principles of the legal framework of land use as well as the role of organizations as bottlenecks for the implementation of sustainability strategies. Students understand the rational of social and economic sciences (methodology, methods). They are able to adopt theoretical concepts to practical questions and use them as a tool to understand the formulation and implementation of energy policy.

Students gain an overview of fundamentals of law and state theory, energy and planning law and learn how this legal framework shapes the renewable energy market.

Recommended reading

Tipler, Mosca: Physics for Scientists and Engineers; Freeman, 6th edition, 2007 (Part I, II, III, IV, V)
Boylestad, Nashelsky, Electronic Devices and Circuit Theory, Prentice Hall, 7th edition
Orrrest M. Mims, Getting Started in Electronics, 12th edition (1994) – *soft copy for the students will be provided*.
Economy & Management: Selected chapters from : Cole, G. a. 2003. Management. Theory and Practice. 6th edition. Cengage Learning (UK) & Parkin, M., Powell, M. and Matthews, K. 2003 Economics, 5th Edition, Harlow: Addison-Wesley; during the module materials will be made available via the learning platform ILIAS

Course prerequisites

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<table>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses
---</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
93951</td><td colspan="2">Module name
Natural Resources and Conversion Technologies</td><td>Semester/return
1st Sem. / annual</td></tr>
<tr><td>Workload/presence
10 ECTS (300 h/100 h)</td><td>Prerequisite module(s)
Scientific Framework for REM</td><td>Follow-up module(s)
Generation and Distribution of Energy</td><td>No. of participants
Max. 75</td></tr>
<tr><td>Teaching form
Lectures, Exercises, Seminar, lab experiments</td><td>Examination form
Written assignment</td><td>Start date
09.01.2023</td><td>Location
tba</td></tr>
<tr><td colspan="4">Module coordinator: Prof. Dr. Stefan Pauliuk (stefan.pauliuk@indecol.uni-freiburg.de)</td></tr>
<tr><td colspan="4">Additional teaching staff
Prof. Dr. Andreas Christen (solar radiation), Prof. Dr. Werner Platzer (solar thermal, solar power), Dr. Ralf Preu (photovoltaics), Prof. Dr. Markus Weiler (water & hydropower), Dr. Sebastian Paczkowski (biomass & bioenergy), Prof. Dr. Dirk Schindler (wind)</td></tr>
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Syllabus

This module gives the students an overview and the fundamental knowledge of different renewable energy sources and their potentials as well as basics of the underlying conversion technologies.

1. Solar Radiation, Photovoltaics & Solar heat (2 weeks)

Solar radiation: Meteorological aspects of the utilization of solar radiation as a renewable energy source: processes, phenomena, solar radiation spectrum, spatial and temporal patterns of radiative fluxes in the atmosphere and at the earth's surface. Calculation of solar irradiation on inclined collectors; methods for determining diffuse and direct solar radiation

Photovoltaics: Basics of solar cell principles and characterisation silicon photovoltaics value chain with focus on cell technology, overview over other photovoltaic technologies, simple design of photovoltaic systems, and calculation of energy gain.

Solar Thermal Energy: Basics of solar thermal energy conversion are given, which includes: flat plate and vacuum tube solar collector design, black and selective absorbers, basics of optical gains and calculation of conductive, radiative and convective heat transfer in solar collectors and piping, solar thermal system concepts for solar domestic hot water and solar assisted heating, hot water storage types. System concepts are addressed, such as forced circulation and natural circulations systems, with low and high flow. Overview on solar concentrating collectors is given. High temperature applications are addressed, such as solar process heat and concentrated solar thermal power (CSP). Eventually, simple economics and system comparison with conventional alternatives are discussed.

2. Wind & Wind Energy (1 week)

Meteorological aspects of the utilization of wind as a renewable energy source are discussed, such as processes, phenomena, spatial and temporal patterns of kinetic energy and airflow in the atmospheric boundary layer.
Furthermore, this part of the module gives an applied overview about wind technology, focusing on performance and feasibility. Main topics are: the evolution of the wind turbine (capacity, components) and the role of electric grids. Additionally, key factors of wind-project development will be analysed: construction pre-requisites, steps, methods and costs. Wind technology perspectives around the world will be part of the module as well.

3. Water & Hydropower (1 week)

This part of the module gives a broad overview about the water cycle and hydrological processes as well as the large number of different technologies and applications for producing hydropower and hydroelectricity. The state of hydropower worldwide and in certain countries will be addressed and calculations for hydropower and hydroelectricity output will be done. Further topics are: hydropower and environment, hydropower and climate change, river ecology scientific discussion on dams), aspects of hydropower economics, sustainable management of hydropower and case studies around the world.

4. Biomass & Bioenergy (1 week)

This part of the module provides general knowledge on biomass abundance and management, the chemical composition of important biomass resources, and all major biomass conversion technologies. The following technologies will be introduced:

- thermo-chemical
- physico-chemical
- bio-chemical

The technologies are linked to their respective raw materials as well as to limitations and chances for bioenergy considering aspects of both management and technology. Class assignments allow students to evaluate bioenergy potential of selected countries considering the three sources of raw material (e.g. forestry, agriculture, waste) and related conversion processes.

Learning goals and qualifications

The diversity of renewable energy harvesting is mediated to the students. They understand the potentials with respect to the spatial availability, the general technologies, the sustainability of renewable energy conversion at given conditions, challenges and risks, as well as solution strategies of many different kinds of renewable energy sources. The students learned the basic concepts of the different conversion technologies and know how the different renewable energy sources can be utilized in order to produce electric power, heat and/or fuel.

1. Solar Radiation, Photovoltaics & Solar heat (2 weeks)

Solar radiation: Comprehension of radiative processes in the atmosphere and at the Earth surface, application of knowledge about solar radiation at the earth’s surface within the context of site assessment, analysis of methods used to quantify solar radiation incident at the earth’s surface.

Photovoltaics: The students will get a brief introduction into the history and application of photovoltaics. They will be taught the working principles of photovoltaics, including the basic mechanisms of the generation of carriers by photon absorption. The focus will be on standard semi-conductor based photovoltaics. They will learn how a solar cell can be described by its characteristic current-voltage-dependence. They will learn about the main mechanisms, which limit the maximum efficiency of a photovoltaic device. They will gain a rough overview on the different technologies how to manufacture photovoltaic modules as well as the most important characterization methods. They will learn a basic approach how to derive the energy yield of a PV system. Finally they will get a first insight into cost and environmental issues.

Solar Heat: The students will understand the working principles of solar collector systems and the main factors of the solar energy utilization. They will learn to estimate approximately the solar gains of solar thermal systems. The main factors influencing the output of system can be judged qualitatively. Within exercises optical solar gains and heat losses as part of the overall energy balance of a collector will be calculated. Based on that quantitative simple estimations of collector performance will be practised. They will understand the main features and the basic differences between concentrating and non-concentrating systems.

2. Wind & Wind Energy (1 week)

Comprehension of airflow patterns in the atmospheric boundary layer, application of knowledge about near-surface airflow within the context of site assessment, analysis of methods used to quantify the wind resource near the ground

The students will be able to understand the role of wind energy from the management perspective and to deduce future scenarios for this technology according to the natural conditions and legal framework of each country/region.

3. Water & Hydropower (1 week)

The students will get general and specific knowledge about the water cycle and hydrological processes, principles, technologies, applications, problems and solutions regarding hydropower, ranging from micro to large systems, and the use of hydropower optimized towards sustainability. The students will be able to calculate the output and economics of hydropower. They will be able to compare, evaluate and manage different aspects of hydropower with the goal of sustainability.

4. Biomass & Bioenergy (1 week)

Within this part of the module, the students will get an understanding on the principals of biomass conversion processes and the related requirements on biomass. Based on presented advantages and disadvantages of different conversion technologies, the students will be able to compare and evaluate these technologies. This basic knowledge on the conversion techniques will enable them to evaluate the different technologies with regard to production of power, heat or fuel. In the frame of the homework the students will apply this knowledge.

Recommended reading

- Duffie-Beckman: Solar Engineering of Thermal Processes.
- Martin Green: Solar Cells: Operating Principles, Technology, and System Applications.
- I. Stober and K. Bucher, 2009: Geothermal Energy, Geothermal Exploration. Springer Verlag, Heidelberg.
- Additional relevant literature will be presented in the module

Course prerequisites

Content of the module “Scientific Framework for REM”

<table>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses
---</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
93140</td><td colspan="2">Module name
Climate and Energy Policy</td><td>Semester/return
1st semester / annual</td></tr>
<tr><td>Workload/presence
5 ECTS-P (150h/60h)</td><td>Prerequisite module(s)
--</td><td>Follow-up module(s)
---</td><td>No. of participants
Max. 75</td></tr>
<tr><td>Teaching form
Lectures + group work assignments</td><td>Examination form
Written assignment, group work presentation</td><td>Start date
20.02.2023</td><td>Location
tba</td></tr>
<tr><td colspan="4">Module coordinators: Prof. Dr. Mario Ragwitz</td></tr>
<tr><td colspan="4">Additional teaching staff: Dr. Sibylle Braungardt, Dr. Veit Bürger, Dr. Vicki Duscha</td></tr>
<tr><td colspan="4">Syllabus
The prevailing focus of the module is on the governance of climate and energy issues and corresponding policies at different levels (international, national, regional), as well as on their interrelation to other policy fields. After a short introduction to the basics of political science, students will be confronted with the wide range of climate and energy issues as well as the resulting conflicts and their role in the international efforts to mitigate climate change. Targets of climate and energy policy will be presented as well as the broad range of related instruments, policy processes, involved stakeholders and their interests.
In particular the module will cover the fundamentals of:
➢ international climate policy, including different concepts of effort sharing and the role of different countries / world regions in international negotiations of mitigation targets,
➢ energy policy, incl. instruments targeted at security of supply, energy efficiency, environmental sustainability,
➢ electricity markets and the impact of energy policy on these markets,
➢ renewable energy policy including basic economic characterization of renewable energies in energy modelling,
➢ the energy transition in Germany.

The module is designed in a very interactive manner and encourages strong participation of the students. After detailed introductions and presentations to the different topics they will be asked to elaborate issues and present the results in a self-organized manner (group work), i.e. by
- conducting country case studies,
- preparation of short presentations on case studies conducted.
Furthermore, various guest speakers and experts from different fields and institutions will be invited to provide expert views and insights on the respective topics.</td></tr>
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Learning goals and qualifications

The main goal of this interdisciplinary module is to provide in-depth knowledge and insights into concepts of energy policy and the international climate regime; the focus of the module is on the connection to strongly related issues and processes, e.g., national and international climate, energy and land use policies. Different scientific disciplines are merged, with the objective to foster an understanding of complex multi-level political issues. This includes

- the presentation of different types of instruments and the role of the policy mix
- the role of different actors and institutional aspects
- different governance levels of energy and climate policy (local, regional, national, international)
- steps in the policy process (design, implementation, monitoring, evaluation, etc)
- role of scenarios (normative, explorative, projective), dealing with uncertainties
- cost aspects (system analytic, distributional effects, external costs)

Development of the following skills

- ability to analyze complex contextual knowledge
- interdisciplinary work
- ability to evaluate policy programmes and instruments
- rhetoric, discussion and presentation skills
- team work
- fostering of problem solving competences

Recommended reading

Metz, B. (2010): Controlling climate change. Cambridge university press. 350 p
http://www.iea.org/policiesandmeasures/climatechange/
http://www.worldenergyoutlook.org/
http://unfccc.int/resource/process/guideprocess-p.pdf
http://www.uneptie.org/energy/publications/pdfs/EmissionsTrading-Feb03.pdf
http://www.bmu.de/files/pdfs/allgemein/application/pdf/reccs_endbericht_kurz_en.pdf
http://www.grida.no/publications/rr/natural-fix/ebook.aspx
http://www.bmu.de/files/english/renewable_energy/downloads/application/pdf/broschuere_ee_zahlen_en.pdf

Course prerequisites

- Teaching context of module “Energy and sustainable development”
- Basic knowledge regarding environmental issues associated to climate change

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses ----			**Instruction Language** English
Module No. **5572**	**Module name** **Optimization and Forecasting for Energy Systems**		**Semester/return** 3rd Sem. / annual
Workload/presence 6 ECTS-P (150h/60h)	**Prerequisite module(s)** Elective I	**Follow-up module(s)** ---	**No. of participants**
Teaching form Lectures, exercises	**Examination form** Written exam	**Start date** 17.10.2022	**Location** t.b.a.

Module coordinator: Prof. Dr. Anke Weidlich

Additional teaching staff:

Syllabus

Optimization and forecasting are very relevant tasks in many domains of energy management and energy economics. The course will cover some of the most prominent optimization and modeling problems in the energy domain, and provides methods for solving such problems. The content includes the following topics:

- Optimization problems in energy economics (e. g. unit commitment, resource scheduling)
- Linear and mixed-integer linear programming
- Dynamic programming
- Multi-criteria decision analysis
- Multiple linear regression
- Time series-based forecasting

The theoretical content will be taught through lectures, including many application examples from energy practice and from academia. There will be in-class exercises, some of which are carried out with standard software tools. Students will prepare a homework that aims at replicating a study using one of the optimization or forecasting methods discussed in the lecture.

Learning goals and qualifications

The students have an overview of different optimization problems in the energy sector and can choose an appropriate method for problem solving. They understand the mathematical background of linear programming, mixed-integer linear programming and other techniques that are widely applied in the energy economy. They are able to formulate mathematical models (objective functions, constraints) and are able to apply optimization methods with the help of computational tools. The students understand the background of different forecasting methods and can carry out forecasts based on time series and multiple linear regression. They can solve the problems with a computer tool. Students are able to formulate their own model for addressing a research challenge, and carry out simple analyses to draw conclusions from model results.

Recommended reading (*available at www.ub.uni-freiburg.de)

- Suhl, L., Mellouli, T.: Optimierungssysteme : Modelle, Verfahren, Software, Anwendungen. 2nd edition, Berlin : Springer, 2009.
- Poler, R., J. Mula, M. Díaz-Madronero: Operations Research Problems: Statements and Solutions, Springer, Berlin / Heidelberg, 2014.
- Williams, H. P.: Model Building in Mathematical Programming, 5th Edition, John Wiley & Sons, 2013.

Course prerequisites

None.

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses **SSE**			**Instruction Language** English
Module No. **5559**	**Module name** **Complex Networks**		**Semester/return** 3rd Sem. / annual
Workload/presence 6 ECTS (180 h/70 h)	**Prerequisite module(s)**	**Follow-up module(s)** Elective II Energy Efficiency	**No. of participants**
Teaching form Lecture with integrated exercises	**Examination form** Written exam	**Start date** 17.10.2022	**Location** Uni Freiburg

Module coordinator:

Dr. Mirko Schäfer

Additional teaching staff

Syllabus

- the language of graph theory
- random graphs, small world and scale-free networks
- centrality measures
- economic and financial networks
- network components and the configuration model
- transport, contagion and diffusion processes on networks
- network synchronization
- network aspects of the electricity system
- large-scale renewable energy networks
- multiscale infrastructure networks

Learning goals and qualifications

After the completion of the course the student is expected to be able to

- describe how complex systems can be represented as networks
- calculate various measures for a given network
- compare the structure of different real world networks
- describe and explain network models covered in the course
- implement and analyse network models in the programming language Python, import data, plot results, visualise networks
- communicate and discuss the methods and results presented in current research papers from the field of complex networks

Recommended reading

- A.L. Barabási, Network Science, available at networksciencebook.com
- M.E.J. Newman, Networks: An Introduction
- Further literature will be announced in class

Course prerequisites

Basic knowledge of matrix and probability theory.

<table>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses
---</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
6002</td><td colspan="2">Module name
Energy System Modeling with Python</td><td>Semester/return
3rd Sem. / annual</td></tr>
<tr><td>Workload/presence
6 ECTS-P (180h: 45h class, 60h preparation, 75h project) / 4 computer lab + integrated lectures</td><td>Prerequisite module(s)
---</td><td>Follow-up module(s)
---</td><td>No. of participants
20</td></tr>
<tr><td>Teaching form
Computer lab and lecture</td><td>Examination form
Project and presentation*</td><td>Start date
17.10.2022</td><td>Location
INATECH</td></tr>
<tr><td colspan="4">Module coordinators: Prof. Dr. Anke Weidlich</td></tr>
<tr><td colspan="4">Additional teaching staff: Jan-Frederick Unnewehr, Ramiz Qussous</td></tr>
<tr><td colspan="4">*Students choose an own research challenge, decide on a model for addressing the challenge, implement it in Python, execute it with appropriate input data, plot and interpret results, and describe the project in a report. They present their project in the class.</td></tr>
<tr><td colspan="4">Syllabus
• General introduction to Python, integrated development environment
• Fundamentals (data types, expressions, conditional execution, iterations, functions, files, matrix operations)
• Algorithms (flowcharts, pseudocode, complexity and runtime estimation)
• Modelling techniques and application examples from energy systems analysis (power flow analysis, merit order models, simulations, and others)
• Relevant data sources for the energy sector
• Data evaluation (data import and export, plotting results)

Incl. mandatory implementation assignments</td></tr>
<tr><td colspan="4">Learning goals and qualifications
The students
• Can apply basic techniques for solving mathematical problems with Python
• Understand engineering problems described in flowcharts, and can translate flowchart descriptions into a computer program
• Can apply Python to solving mathematical problems in different scientific fields, especially in the energy and sustainability domain
• Can analyse energy system models implemented in Python
• Can create an appropriate model for approaching a research question in the energy field and implement it in Python</td></tr>
<tr><td colspan="4">Recommended reading
• Literature will be announced in the lecture
• Starting book: A. Sweigart, Automate the Boring Stuff with Python: Practical Programming for Total Beginners, No Starch Press (2015)</td></tr>
<tr><td colspan="4">Course prerequisites (recommended)
Energy System Operations</td></tr>
</table>

Course

M.Sc. Renewable Energy Engineering and Management

Availability to other courses	**Instruction Language**
---	English

Module No.	**Module name**		**Semester/return**
97001	**Smart Grids**		3rd Sem. / annual
Workload/presence	**Prerequisite module(s)**	**Follow-up module(s)**	**No. of participants**
5 ECTS (150 h/60 h)			25
Teaching form	**Examination form**	**Start date**	**Location**
Lectures, Exercises, Seminar, lab experiments	Written exam	21.10.2022	University of Freiburg; Fraunhofer ISE

Module coordinator:

Prof. Dr. Christof Wittwer (christof.wittwer@ise.fraunhofer.de)

Additional teaching staff

Dr. Bernhard Wille-Haussmann; Dr. Robert Kohrs, NN

Syllabus

1. Energy transport and grids
   - 1.1. Energy and power definition;
   - 1.2. Grid bounded transport: gas; heat; electricity
   - 1.3. Power analysis: sankey; efficiency; duration curves;
2. Distributed and centralized generation
   - 2.1. Transformation into renewable energy system
   - 2.2. Grid structure; distribution and transmission grid
   - 2.3. Components; power plants; storage, loads
   - 2.4. Grid integration; flexibility; cross energy management
   - 2.5. Economics: liberalized energy market; grid operation
   - 2.6. Demand Responce, micro grids
   - 2.7. Control and communication system: smart grid architecture models
3. System theory
   - 3.1. System modeling and simulation: application domains
   - 3.2. Linear and differential equations:
   - 3.3. Thermal-electric energy system simulation: examples
   - 3.4. Controls and Optimization of grid integrated energy systems
4. Grid theory
   - 4.1. DC and AC Circuit calculation;
   - 4.2. Transient and stationary power flow
   - 4.3. Grid integration: reactive and active power flow contol

Learning goals and qualifications

Students will learn to use the basics of designing grid integrated energy systems; fundamental aspects of power and energy definition, overview on plant and smart grid technologies, calculation and simulation of energy systems; fundamental aspects of power flow calculation and grid theory.

Recommended reading

Duffie and Beckman: Solar Engineering of Thermal Processes. ISBN: 978-0-470-87366-3
Volker Quaschning: Renewable Energy and Climate Change: ISBN 978-0-470-74707-0.
European SmartGrids technology platform: http://ec.europa.eu/research/energy/pdf/smartgrids_en.pdf
Smart Grid Communications and Networking; Ekram Hossain isbn: 9781107014138
Modelling and Analysis of Electric Power Systems: Göran Andersson:
http://www.eeh.ee.ethz.ch/uploads/tx_ethstudies/modelling_hs08_script_02.pdf

Course prerequisites: “Energy System Operations”

<table>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses
---</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
2080</td><td colspan="2">Module name
Modelling and System Identification</td><td>Semester/return
3rd Sem. / annual</td></tr>
<tr><td>Workload/presence
6 ECTS-P (180h: 64h class, 116h self-study) / 3 lectures + 1 exercise</td><td>Prerequisite module(s)
---</td><td>Follow-up module(s)
---</td><td>No. of participants</td></tr>
<tr><td>Teaching form
Lecture and exercises</td><td>Examination form
Written or oral examination</td><td>Start date
17.10.2022</td><td>Location
IMTEK; Lehrstuhl Systemtheorie</td></tr>
<tr><td colspan="4">Module coordinators: Prof. Dr. M. Diehl</td></tr>
<tr><td colspan="4">Additional teaching staff:</td></tr>
<tr><td colspan="4">Syllabus
Aim of the module is to enable the students to create and identify models that help to describe and predict the behaviour of dynamic systems. In particular, students shall become able to use input-output measurement data in form of time series to identify unknown system parameters and to assess the validity and accuracy of the obtained models.</td></tr>
<tr><td colspan="4">Learning goals and qualifications
Linear and Nonlinear Least Squares, Maximum Likelihood and Bayesian Estimation, Cramer-Rao-Inequality, Recursive Estimation, Dynamic System Model Classes (Linear and Nonlinear, Continuous and Discrete Time, State Space and Input Output, White Box and Black Box Models), Application of identification methods to several case studies. The lecture course will also review necessary concepts from the three fields Statistics, Optimization, and Systems Theory, where needed.</td></tr>
<tr><td colspan="4">Recommended reading
• Lecture manuscript
• Ljung, L. (1999). System Identification: Theory for the User. Prentice Hall
• Lecture manuscript "System Identification" by J</td></tr>
<tr><td colspan="4">Course prerequisites (recommended)
Knowledge of
• Mathematics I for Engineers and Computer Scientists
• Mathematics II for Engineers
• Differential Equations
• Systems Theory and Feedback Control</td></tr>
</table>

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses ---			**Instruction Language** English
Module No. **4113**	**Module name** **Energy in Buildings: components and systems for energy supply**		**Semester/return** 3rd Sem. / annual
Workload/presence 6 ECTS	**Prerequisite module(s)**	**Follow-up module(s)**	**No. of participants** 15
Teaching form Lecture (min. 80% attendance)	**Examination form** Written or oral	**Start date** 17.10.2022	**Location** INATECH
Module coordinators: Prof. Dr. H.-M. Henning			

Syllabus

Covered technologies:
• Burners, condensing boiler technology
• Combined heating and power (CHP) units for buildings
• Heat transformation: principles, compression, absorption, adsorption
• Solar energy utilization: principles, solar thermal collectors, photovoltaics applied in buildings
• Energy storage: thermal storage, electrical storage and their system integration
Beside the technologies overall systems are analysed and specific figures of merit to assess different technical solutions are defined and applied. Basic methods for cost assessment as well as methods to assess building sustainability are presented and discussed.

Exercises are included into the lecture.

Learning goals and qualifications

The students know important technical components for energy supply (heating, cooling, air dehumidification) of buildings. Classical processes such as gas burners and compression chillers are covered as well as processes involving renewable energy (especially solar energy and ambient heat). The students are familiar with the physical principles of these processes and are able to derive key figures of merit from these principles. They are aware of the state of the art in these technologies and they can describe focal points of recent research and development work in this field. They are able to assess and compare different energy supply systems for buildings based on economic, ecologic and energy related figures of merit. They are also familiar with some basic methodologies for economic assessment of technical systems (life cycle cost assessment).

Recommended reading

Ursula Eicker: Solar Technologies for Buildings. Springer. ISBN-13: 978-0471486374
Solar Cooling Handbook 3rd Revised & enlarged Edition. by Hans-Martin Henning (Editor), Mario Motta (Editor), Daniel Mugnier (Editor). Ambra. ISBN-13: 978-3990434383

Course prerequisites (recommended)

Energy Storage, Solar Energy

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses ---			**Instruction Language** English
Module No. **8010**	**Module name** **Energy Storage**		**Semester/return** 3rd Sem. / annual
Workload/presence 5 ECTS-P (150h: 56h class, 94h self-study) / 3 lectures + 1 exercise	**Prerequisite module(s)** ---	**Follow-up module(s)** ---	**No. of participants** -
Teaching form Lecture and exercises	**Examination form** Written or oral examination	**Start date** 19.10.2020	**Location** INATECH
Module coordinators: D. Schossig			
Additional teaching staff: A. Georg			

Syllabus

1. Introduction and motivation energy storage (electric, thermal, PtG): Large-scale integration of renewable energies and the role of energy storage; technical requirements of power grids; overview of energy storage options and applications; key parameter of energy storage systems; technical requirements of storage systems; economic analyses for storage systems
2. Basics of energy storage systems: Mechanical (pumped hydro, CAES, fly wheels); Electric (SuperCaps); Electrochemical (Lead-acid, NiCd, NiMh, Lithium-ion; Sodium-ion; NaS / NaNiCl); thermal storage systems; chemical storage and PtG systems
3. Design of battery systems (focus Lithium-ion): Test and characterization of cells; Battery module and system design (components, construction, cooling); Safety issues; Battery management; Thermal management; System integration (system options, power and communication interface); Peripheral components (inverter, energy management)
4. Design of thermal storage systems
Description of technologies: sensible heat storage, latent heat storage, thermochemical storage. Technical applications: long term storage, short term storage, from cold storage to high temperature storage. Component and system layout, best case examples, limits and future expectations
5. Design of hydrogen storage and PtG systems: different system layouts and main components of hydrogen and PtG storage systems, water electrolysis as core component for PtG systems, advantages and drawbacks for repowering in fuel cells and thermal engines, best case examples of PtG installations, intersectoral extention to further Power-to-X technologies

The lecture will be accompanied by a weekly exercise to deepen the understanding of the lecture's content and to discuss further details.

Learning goals and qualifications

• Understanding the necessity of energy storage (short-term, mid-term, seasonal) for stationary applications (electric, thermal and chemical) as well as their technical and economic requirements

• Basic knowledge of different energy storage technologies such as pumped-hydro, SuperCaps, batteries, and thermal storage systems as well as hydrogen and Power-to-Gas (PtG) solutions

• Knowledge in design of battery systems with a focus on lihtium-ion technologies

• Knowledge in design of thermal storage systems

• Knowledge in design of hydrogen storage and PtG systems

Recommended reading
T. Letcher: Storing Energy G. Pistoia: Lithium-Ion Batteries Advances and Applications A. Jossen: Moderne Akkumulatoren richtig einsetzen J.-C. Hadorn: Thermal energy storage for solar and low energy systems P. Moseley and J. Garche: Electrochemical Energy Storage for Renewable Sources and Grid Balancing
Course prerequisites (recommended)
Basic understanding of Engineering Physics and Engineering Chemistry

<table>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses
---</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
97010</td><td colspan="2">Module name
Photovoltaics 1</td><td>Semester/return
3rd Sem. / annual</td></tr>
<tr><td>Workload/presence
5 ECTS (150 h/60 h)</td><td>Prerequisite module(s)
Natural Resources and Conversion Technologies</td><td>Follow-up module(s)
Photovoltaics 1</td><td>No. of participants
Max. 25</td></tr>
<tr><td>Teaching form
Lectures, Exercises, Seminar, lab experiments</td><td>Examination form
Written assignment</td><td>Start date
07.11.2022 (distributed over 6 weeks)</td><td>Location
University of Freiburg
Fraunhofer ISE</td></tr>
<tr><td colspan="4">Module coordinator: Prof. Dr. Hans-Martin Henning</td></tr>
<tr><td colspan="4">Additional teaching staff: Dr. Ralf Preu (ralf.preu@ise.fraunhofer.de)</td></tr>
</table>

Syllabus

In this module, fundamental concepts and a deeper understanding of photovoltaic technology are presented to the students

- Basics of semiconductor physics
- Photogeneration and recombination, carrier transport
- pn- Junction and IV-characteristics
- Silicon: Quartz, metallurgical silicon, crystallization, wafer cutting
- Industrial silicon solar cell production and advanced approaches for higher efficiency
- Module technology
- Cost of ownership
- Characterization of cells / material
- Loss mechanisms and improvements
- High efficiency cell concept
- Introduction to PV systems

Learning goals and qualifications

As the first step in this course the student will get an overview about the basic concepts of semiconductors. This is the prerequisite for the understanding of the principles of solar cell physics which is one of the main topics of this course. Subsequently the student will study the whole production chain of silicon solar cells starting from quartz via solar cell production to module fabrication. This will be accompanied by an in-depth cost analysis of the solar cell production. The students will understand main loss mechanisms of silicon solar cells and the advantages of high-efficiency cell concepts

Recommended reading

1. Arno Smets, Klaus Jager : Solar Energy: The Physics and Engineering of Photovoltaic Conversion, Technologies and Systems, 2016, available as cost-free download for kindle via Amazon (status 16.8.2016)
2. B. Streetman, Solid State Electronic Devices
3. S.M. Sze, Physics of Semiconductor Devices
4. Martin A. Green, Solar Cells: Operating Principles, Technology, and System Applications
5. Peter Würfel, Physics of Solar Cells
6. Jenny Nelson, The Physics of Solar Cells

Course prerequisites

<table>
<tr><td colspan="4">Basic knowledge of semiconductor physics, “Natural Resources and Conversion Technologies - Photovoltaics”</td></tr>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses
---</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
97012</td><td colspan="2">Module name
Photovoltaics 2</td><td>Semester/return
3rd Sem. / annual</td></tr>
<tr><td>Workload/presence
5 ECTS (150 h/60 h)</td><td>Prerequisite module(s)
Photovoltaics 1</td><td>Follow-up module(s)</td><td>No. of participants
Max. 25</td></tr>
<tr><td>Teaching form
Exercises, Seminar</td><td>Examination form
Seminar Presentation, Report</td><td>Start date
09.01.2023 (distributed over 6 weeks)</td><td>Location
University of Freiburg
Fraunhofer ISE</td></tr>
<tr><td colspan="4">Module coordinator: Prof. Dr. Hans-Martin Henning</td></tr>
<tr><td colspan="4">Additional teaching staff: Dr. Ralf Preu (ralf.preu@ise.fraunhofer.de)</td></tr>
<tr><td colspan="4">Syllabus
A seminar about specific topics of PV technology, systems and costs thereof (e.g. review of different approaches for the calculation of levelized cost of PV electricity or Review of PV Technology for industrial high efficiency solar cells). The three week course will be distributed into 3 phases.
1st week: topic collection, group definition (up to 5 groups min. 2 person per group), introduction to the topic by a tutor including distribution of literature and work within the group, study of literature, one additional appointment with tutor at the end of the week to discuss open points and structure of the presentation and report.
2nd week: preparation of final presentation, two-day seminar with presence requested by all, each individual member of a group has to give a sub-presentation.
3rd week: Groups will have to hand in a report on the review (max. 10 pages) at the beginning of the week. At the end of the week a short exam will be written on all presented topics.
High quality reports might be handed in as abstracts for an international photovoltaic conference. Preparation of such an abstract and paper is beyond the scope of the course itself but can be supported by the academic staff.</td></tr>
<tr><td colspan="4">Learning goals and qualifications
Based on the knowledge acquired in Photovoltaics 1 this course will deepen the knowledge of the students in PV. Furthermore students will study group work and learn to review a scientific topic in a short given time. The students will gain practice in oral presentation and written publication on a scientific level.</td></tr>
<tr><td colspan="4">Recommended reading
See Photovoltaics 1 – specific literature will be distributed at the beginning of the course</td></tr>
<tr><td colspan="4">Course prerequisites
Successful participation in Photovoltaics 1 or equivalent.</td></tr>
</table>

<table>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses
---</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
97015</td><td colspan="2">Module name
Solar Thermal Energy 2</td><td>Semester/return
3rd Sem. / annual</td></tr>
<tr><td>Workload/presence
5 ECTS (150 h/60 h)</td><td>Prerequisite module(s)
Solar Thermal Energy 1</td><td>Follow-up module(s)</td><td>No. of participants
Max. 25</td></tr>
<tr><td>Teaching form
Project, Seminar, Discussion Forum</td><td>Examination form
Seminar presentation, Report</td><td>Start date
09.01.2023 (distributed over 6 weeks)</td><td>Location
University of Freiburg
Fraunhofer ISE</td></tr>
<tr><td colspan="4">Module coordinator: Prof. Dr. Werner Platzer</td></tr>
<tr><td colspan="4">Additional teaching staff: Dr. Korbinian Kramer, Dr. Manuel Lämmle, Dr. Alex Morgenstern</td></tr>
<tr><td colspan="4">Syllabus
A seminar about specific topics of solar thermal technology, systems and economics thereof (e. g. review of different approaches for the determining the cost-efficiency of solar thermal projects in relation to other renewables or energy-efficiency measures or comparison of concentrator technologies for industrial processes or for concentrated solar thermal power CSP). The six-week course will be distributed into 3 phases (spread out over 6 weeks!).
1st phase: topic collection, group definition (1-3 persons per group), introduction to the topic by a tutor including distribution of literature and work within the group, study of literature, one additional appointment with tutor at the end of the week to discuss open points and structure of the presentation and report.
2nd phase: preparation of final presentation, two-day seminar with presence requested by all, each individual member of a group has to give a sub-presentation.
3rd phase: Groups will have to hand in a report on the review (max. 10 pages) at the beginning of the phase 3. Within phase 3 there is opportunity to discuss and ask questions in Online Forum and a meeting on the results presented by all participants. At the end of the phase 3 a short exam will be written on all presented topics.
High quality reports might be handed in as abstracts for an international conference like Eurosun or Solar PACES Conferences. Preparation of such an abstract and paper is beyond the scope of the course itself but can be supported by the academic staff.</td></tr>
<tr><td colspan="4">Learning goals and qualifications
Based on the knowledge acquired in Solar Thermal Systems 1 this course will deepen the knowledge of the students in Solar Thermal technology and applications. Furthermore students will study and work in groups and learn to review a scientific topic in a short given time. The students will gain practice in oral presentation and written publication on a scientific level.</td></tr>
<tr><td colspan="4">Recommended reading
See Solar Thermal Systems 1 – specific literature will be distributed at the beginning of the course</td></tr>
<tr><td colspan="4">Course prerequisites
Successful participation in Solar Thermal Systems 1 or equivalent (may be discussed with the module coordinator)</td></tr>
</table>

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses ---			**Instruction Language** English
Module No. **97021**	**Module name** **Managing RE Projects - Case Studies**		**Semester/return** 3rd Sem. / annual
Workload/presence 5 ECTS-P (150h/60 h)	**Prerequisite module(s)** Introduction to Business Management	**Follow-up module(s)** ---	**No. of participants** max. 25
Teaching form Lectures, guest lectures, case studies	**Examination form** Seminar presentation + report	**Start date** 07.11.2022	**Location** Online; (t.b.a.)
Module coordinator: PD Dr. Chantal Ruppert-Winkel (chantal.ruppert@envgov.uni-freiburg.de)			
Teaching staff:			

Syllabus

The module “Managing RE Projects - Case Studies” will deepen the knowledge gained in the management lectures before through application in energy management examples. During the three weeks, the students will work on selected "real life” management case studies for energy-projects, each to be done by smaller groups of students. Students will work as consultants for the commissioning companies on given work orders. They will have to organize autonomously on real world project cases (under the supervision of the lecturer and in contact with the companies); outcomes of the work may be used by the companies in their future operations.

The course will also contain an introduction into project management, and guest lectures from management experts in RE-organizations/ -projects from different fields.

At the end of the module, students will give a presentation on their results to the commissioning companies and the class and have to provide a report.

Note: This is a module aiming to practice professional work assignments. While there will be continuous support by the teaching staff, students’ motivation and willingness for autonomous work in groups is essential.

Learning goals and qualifications

- application of business management instruments
- strategic thinking and application of strategic management concepts
- project management skills and experiences
- insights into different RE management fields, challenges and organizations
- in-depth work on real life case studies
- Additional general skills: rhetoric, discussion and presentation skills, competence for team work

Recommended reading

During the module materials will be made available via the learning platform ILIAS

Course prerequisites

None.

<table>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses
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English</td></tr>
<tr><td>Module No.
97022</td><td colspan="2">Module name
Landscape, Nature Protection, Landuse conflicts</td><td>Semester/return
3rd Sem. / annual</td></tr>
<tr><td>Workload/presence
5 ECTS-P (150/60h)</td><td>Prerequisite module(s)</td><td>Follow-up module(s)</td><td>No. of participants
Max. 25</td></tr>
<tr><td>Teaching form
Project work</td><td>Examination form
Project report, presentation, group work and excursion</td><td>Start date
28.11.2022</td><td>Location
t.b.a.</td></tr>
<tr><td colspan="4">Module coordinator: Prof. Dr. Barbara Koch</td></tr>
<tr><td colspan="4">Additional teaching staff: Mirko Mälicke, Joao Paulo Pereira</td></tr>
<tr><td colspan="4">Syllabus
Introduction to the significance renewable energy projects for environment and landscapes

An introduction to the interrelation of the renewable energy and the impact on environment how renewable energy strategies change landscapes. Students actively will identify practical examples to study the changes in environment and landscapes related to renewable energy projects and policies. An outline is given between the difference of Life Cycle Assessment (LCA) and Environmental Impact Assessment (EIA) what is the meaning of LCA compared to EIA.

How to assess the impacts and interdependencies with the environment.

The data needs and methods for performing an EIA, are described. The scheme of an EIA process is presented and discussed. Tools for data assessment and performing (GIS) the EIA introduced. They study a real case. They reflect the situation for the EIA implementation in reference to their home countries.

Case study

The students select a case from the renewable energy field for an EIA study. They collect data and information supported by the lecturer team. They perform a simplified EIA for one case. They present the result in the group and discuss the problems reflecting the situation in different regions of the world.</td></tr>
<tr><td colspan="4">Learning goals and qualifications
Knowledge about environmental and landscape problems connected with renewable energy. Information about EIA and the EIA process. Students will be able to apply the tools for data assessment and EIA performance. They will reflect the problems on international basis.</td></tr>
<tr><td colspan="4">Recommended reading
Calvert K., Pearce J.M., Mabee: Toward renewable energy geo-information infrastructures: Applications of GIScience and remote sensing that build institutional capacity, Renewable and Sustainable Energy Reviews, doi: 10.1016/j.rser.2012.10.024</td></tr>
<tr><td colspan="4">Course prerequisites:
-</td></tr>
</table>

<table>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses
This module is offered as core and elective module to the MSc programme Environmental Sciences</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
64101</td><td colspan="2">Module name
Environmental Economics</td><td>Semester/return
3rd Sem. / annual</td></tr>
<tr><td>Workload/presence
5 ECTS-P (150/60h)</td><td>Prerequisite module(s)</td><td>Follow-up module(s)</td><td>No. of participants
Max. 10</td></tr>
<tr><td>Teaching form
Lecture + Tutorial</td><td>Examination form
Written exam</td><td>Start date
28.11.2022</td><td>Location
online</td></tr>
<tr><td colspan="4">Module coordinator: Prof. Dr. Stefan Baumgärtner</td></tr>
<tr><td colspan="4">Additional teaching staff: Joaquín Felber</td></tr>
</table>

Syllabus

In this course, students will learn how to analyze the natural environment and natural resources from an economic perspective. To this end, students will learn intermediate and advanced concepts and methods from ecological, environmental and resource economics, and apply them to analyze economy-environment systems.
Topics to be covered include the following:

- Review of basic concepts from microeconomics (utility, scarcity, optimization, efficiency, markets)
- Welfare analysis of markets, market failure and market regulation:
  - public goods
  - common-pool-resources
  - externalities
- Economic valuation of environmental quality and natural resources
  Decision-making under uncertainty: risk, resilience, and insurance

Learning goals and qualifications

1 = Knowledge: students know advanced theories, methods and empirical facts of environmental economics and can reproduce them
2 = Understanding: students are able to critically reflect the economic approach to analyzing the natural environment, including its premises and limitations, and can explain it in a comprehensible manner
3 = Application: students can independently apply advanced theories and methods of environmental economics to simple problems of the natural environment and resources
4 = Analysis: students are able to systematically analyze the mutual interdependencies between economic and environmental variables at an advanced level

Recommended reading

There is no single textbook for this course. References for several chapters of the course include:

- M. Common and S. Stagl: *Ecological Economics. An Introduction*, Cambridge University Press, 2005
- H.E. Daly and J. Farley: *Ecological Economics. Principles and Applications*, Washington DC: Island Press, 2004
- Endres and V. Radke*: Economics for Environmental Studies. A Strategic Guide to Micro- and Macroeconomics*, Springer, 2012
- N. Hanley, J.F. Shogren and B. White: *Environmental Economics in Theory and Practice*, 2nd edition, Palgrave Macmillan, 2007

R. Perman, Y. Ma, J. McGilvray and M. Common: *Natural Resource and Environmental Economics*, 3rd edition, Pearson Education, 2003

Course prerequisites:

- See details on HISinOne

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses: This module is offered as elective to the MSc programmes Environmental Sciences, MEG, and Forest sciences			**Instruction Language** English
Module No. 64087	**Module name** **Life cycle management**		**Semester/return** 3rd Sem. / annual
Workload/presence 5 ECTS-P (150h/60h)	**Prerequisite module(s)** ---	**Follow-up module(s)** ---	**No. of participants** Max. 35
Teaching form Lectures, exercises, group work	**Examination form** Written assignment (33%), Term paper + group work (67%)	**Start date** 09.01.2023	**Location** Tba.
Module coordinator: Prof. Dr. Stefan Pauliuk (stefan.pauliuk@indecol.uni-freiburg.de)			
Additional teaching staff Johan Velez			

Syllabus

The course enables participants to conduct, interpret, document, and present life cycle assessment studies of products or technical installations using state-of-the-art tools and databases.

During the first half of the course, the motivation behind and theory of life cycle assessment, including the modelling of life cycle inventories and life cycle impact assessment, is presented. The participants conduct exercises and study the relevant literature.

During the second half, the participants learn how to conduct and document a life cycle assessment study that meets both ISO and scientific standards. The participants form small groups of 2-3, chose a product or installation, and perform a life cycle management case study. The final report on the case study is due at the end of the module. It will be graded and the result will account for two thirds of the final grade of the course.

During the second half, background lectures and discussions on the potential, limits, applications, and future development of life cycle management will be held.

A written exam (1.5 hours), the result of which accounts for one third of the final grade, will be held at the end of the course.

The module is interactive and encourages strong student participation.

Learning goals and qualifications

- Basic knowledge of quantitative systems analysis of human-environment systems, basics of material and energy flow analysis.
- Detailed knowledge about the state of the art, the software, and databases of life cycle assessment according to the standards ISO 14040 and 14044.
- Basic knowledge of life cycle impact assessment methods.
- Soft skills: discussion, scientific writing skills, capacity for team work.
- At the end of the course, the successful participant will be able to conduct, interpret, document, and present life cycle assessment studies of products or technical installations using state-of-the-art tools and databases.

Recommended reading

- LCA Textbook: http://www.lcatextbook.com/. Much of the basic material of the course will be based on this book.
- OpenLCA tutorials (http://www.openlca.org/videos).
- Manual of the ReCiPe impact assessment method (http://www.lcia-recipe.net/file-cabinet/ReCiPe_main_report_MAY_2013.pdf).

Course prerequisites

Calculations with Excel, Basic knowledge on vectors, matrices, matrix multiplication and matrix inversion.

Important: This course requires each participant to work on her/his own laptop with the openLCA software (http://www.openlca.org/) and the ecoinvent database installed. openLCA is freeware. A copy of the ecoinvent database will be provided at the beginning of the course.

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses This module is offered as elective to the MSc programmes MEG, Environmental Sciences, and Forest sciences			**Instruction Language** English
Module No. 97024	**Module name** **Environmental and Energy Transition Law**		**Semester/return** 3rd Sem. / annual
Workload/presence 5 ECTS-P (150h/60h)	**Prerequisite module(s)** ---	**Follow-up module(s)** ---	**No. of participants** Max. 25
Teaching form Socratic lectures, group and individual work, presentations, discussions	**Examination form** SL Written assignment (pass/fail) PL Written assignment (30%, 60 min.), PL Written individual report (3000 words) OR group presentation and report (60 min. / group and 750 words / person, 70%)	**Start date** 09.01.2023	**Location** Tba.
Module coordinator: Jun-Prof. Cathrin Zengerling, e-mail: cathrin.zengerling@enrlaw.uni-freiburg.de Prof. Dr. Errol Meidinger, email: eemeid@buffalo.edu			
Additional teaching staff Invited experts from the private and public sector			

Syllabus

In this module students gain fundamental knowledge of environmental and energy transition law from multi-level governance and international comparative perspectives. They acquire sector-specific knowledge of environmental law in the fields of climate change, air pollution, water, oceans, biodiversity, nature protection, chemicals and waste/circular economy law. With regard to energy transition law, students become familiar with energy and planning law directed to energy efficiency and the switch from fossil fuel based to renewable energy in the sectors of electricity, heating/cooling and mobility.

Throughout the course, students learn about different legal instruments and their strengths and weaknesses in reaching regulatory goals. Both, public and private law perspectives as well as different legal traditions such as common and civil law approaches are covered. Students also get insights into the role of environmental protection and the energy transition in other international legal regimes such as world trade, investment and human rights law.

The course is taught interactively and active participation of students is encouraged. Students become familiar with various primary legal documents such as (excerpts of) international treaties, European directives, constitutions, national laws, administrative permits, land use plans as well as decisions of the judiciary, and learn how to work with them. Students apply and deepen their knowledge under guidance of the instructors in their specific fields of interest via case studies. Throughout the course, various soft skills such as debating in socratic discussions, scientific writing, interdisciplinary and intercultural teamwork are imparted.

Learning goals and qualifications

In this module students learn to:

- identify the main types and instruments of environmental and energy transition law and their distinctive characteristics (1)(2);
- understand interactions and conflicts between different types, sources and instruments of environmental and energy transition law (2);
- assess the inherent strengths and limitations of environmental and energy transition law for environmental and energy governance (5);
- realize that there are alternative ways of structuring environmental and energy transition responsibilities and powers through law (2)(4);
- formulate legal and policy arguments relevant to future environmental and energy transition law development (6);
- critically and intelligently evaluate arguments for legal change (4);
- understand the relationship between scientific knowledge, social movements, and environmental/ energy transition law (2);
- apply basic skills of legal research and legal arguments to relevant case studies (3)(6).

Classification of cognitive skills following Bloom (1956):

1 = *Knowledge*: recalling facts, terms, basic concepts and answers; 2 = *Comprehension*: understanding something; 3 = *Application*: using a general concept to solve problems in a particular situation; 4 = *Analysis*: breaking something down into its parts; 5 = *Synthesis*: creating something new by putting parts of different ideas together to make a whole; 6 = *Evaluation*: judging the value of material or methods.

Recommended reading

Sands, P., & Peel, J. (2018). *Principles of international environmental law*. Cambridge University Press.

Meidinger, Errol (2008), "Property Law for Development Policy and Institutional Theory: Problems of Structure, Choice and Change." In David Mark, Barry Smith, and Isaac Ehrlich, *The Mystery of Capital and the New Philosophy of Social Reality*. Chicago: Open Court Publishing, pp.193-227.

Reading material will be provided during the course via the e-learning platform ILIAS.

Course prerequisites

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Module number 95990	Module name Elective: Technology Assessment – Theory and Practice	
Course of study M.Sc. Environmental Governance	**Type of course** Elective	**Semester / Rotation** 3rd/ Winter Term
Teaching methods lectures, plenary discussions, group work	**Prerequisites for attendance** None	**Language** English
Type of examination (Final Grade Composition) 1) PL Literature Review (Individual assessment of a self-chosen TA study along guiding questions), max. 2500 words (4 pages) (50%) 2) PL Group Research Report, 15-40 pages (50%) *Participation in discussions & presentations is obligatory; not graded		**ECTS-LP (Workload)** 5 (150h)
Module coordinator apl. Prof. Dr. Philipp Späth, Email: spaeth@envgov.uni-freiburg.de		**SWS** 4

Additional teachers involved

Additional faculty and external experts on various topics will be involved.

Syllabus

As environmental limitations of current economic regimes and lifestyles are increasingly recognized, hope is often directed towards technological innovations (e.g. resource efficiency, 'green' technologies). Assumptions about the 'superiority' of certain technologies are a precondition for any attempt to accelerate the development and diffusion of these technologies by means of science, technology and innovation governance. However, to what extent particular technological innovations can in fact alleviate pressure on natural resources is hard to assess, particularly in the early stages of their development.

We study the promises, methods and practices involved in systematic Technology Assessments (TA) and their role in problematizing the potentials and risks involved in technological change. Starting from an overview of approaches, institutions and methods of TA, we aim to understand the dilemmas of such endeavors and how people tried to overcome them. You will first evaluate a self-chosen TA study that has been published by a recognized TA institution against common criteria. The second and third week of the module are dedicated to the development of your own technology assessment of a specific aspect important to an international hydrogen economy as promoted by the previous German Government: https://www.bmbf.de/bmbf/en/home/_documents/west-africa-can-become-the-cli-energy-powerhouse-of-the-world.html .

You will develop a TA study on a self-chosen aspect of a future hydrogen economy in a team of three to sixteen students. On the way, you will gain insights into how parliamentarian TA is conducted by the German TAB (which has been commissioned with a study on opportunities and risks of hydrogen partnerships and technologies in developing countries, too: https://www.tab-beim-bundestag.de/english/projects_opportunities-and-risks-of-hydrogen-partnerships-and-technologies-in-developing-countries.php).

Learning goals and qualifications

In this module students learn to:

- describe various objectives and institutional forms of technology assessment (1, 4);
- understand the assumptions and world views that influenced various approaches to TA (2, 4);
- be fluent with TA terminology and practices (3);
- identify different challenges and dilemmas of expertise or consensus-oriented methods for TA (5);
- evaluate and criticize TA studies of various scopes (6);
- apply research methods (analysis of literature, interview techniques etc.) (3);

- position themselves with regard to different approaches to technology assessment (6);
- assess the potentials and risks potentially involved in various forms of urban food production (3-6).

Classification of cognitive skills following Bloom (1956):

1 = *Knowledge*: recalling facts, terms, basic concepts and answers; 2 = *Comprehension*: understanding something; 3 = *Application*: using a general concept to solve problems in a particular situation; 4 = *Analysis*: breaking something down into its parts; 5 = *Synthesis*: creating something new by putting parts of different ideas together to make a whole; 6 = *Evaluation*: judging the value of material or methods.

Core readings

A list of relevant texts will be made available at the start of the course; readings themselves will be made available online via Ilias. Introductory reading (pdf available on request):

Grunwald, A. (2019). "Technology assessment in practice and theory". Oxford, Routledge. pp. 1-12.

<table>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses
----</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
97025</td><td colspan="2">Module name
Regulation and Assessment of the Systemic Aspects of the Energy Transition</td><td>Semester/return
3rd Sem. / annual</td></tr>
<tr><td>Workload/presence
5 ECTS-P (150h/60h)</td><td>Prerequisite module(s)</td><td>Follow-up module(s)
---</td><td>No. of participants
Max. 25</td></tr>
<tr><td>Teaching form
Socratic lectures, group work, presentations</td><td>Examination form
Written assignment, group work presentation</td><td>Start date
30.01.2023</td><td>Locations
Online</td></tr>
<tr><td colspan="4">Module coordinator: Prof. Dr. Dierk Bauknecht</td></tr>
<tr><td colspan="4">Additional teaching staff: Guests t.b.a.</td></tr>
</table>

Syllabus

In this module students gain fundamental knowledge of the system implications of renewable energies that result from the main characteristics of electricity generation from renewables, such as their variability, their low marginal costs and the changing geographical distribution. This includes three main steps:

- First, the module explores what the various system implications of renewables are and which options are available and developments take place to adapt the system accordingly.
- Second, it deals with the assessment of these options from various perspectives, especially economic and social perspectives, how this is reflected in stakeholder positions and how such an assessment can be used to inform policy-making.
- Third, the module covers policy and regulatory options to address these system implications. Which regulatory options exist, what are their pros and cons and how are they implemented in different constituencies?

The focus is not on system implications in a narrow engineering sense, but the module takes a broader look at how the power and energy system does transform and needs to transform in order to implement a system based on renewables. This includes the following aspects: Grid infrastructure; flexibility requirements; various forms of centralisation and decentralisation of power systems, sector integration; market design.

The module applies an interdisciplinary approach. It is not based on a any specific methodological approach, but rather explores what instruments are needed and useful for dealing with the above questions. The module also introduces system transformation thinking.

The module will introduce these issues at a general level and with a focus on Germany in a European context as a specific case. Students will then apply the insights to other countries or to specific system options. Active participation of students is expected throughout the course.

Learning goals and qualifications

In this module acquire knowledge on three levels:

1) Energy system knowledge: What are key system implications of renewables, options to deal with them and related regulatory approaches? What are the implications of system transformation? This includes technical, economic, social and policy knowledge.
2) How can the various options available be assessed and what needs to be taken into account for that purpose in a real-world and policy context? How can assessments made by different stakeholders be judged?
3) How can the results be presented? Discussion, presentation and writing

Recommended reading
IEA-RETD (2015) Integration of Variable Renewables (RE-integration), [A. Conway; Mott MacDonald] IEA Implementing Agreement for Renewable Energy Technology Deployment (IEA-RETD), Utrecht, Netherlands http://iea-retd.org/archives/publications/re-integration Bauknecht, D., Heinemann, C., Seebach, D., Vogel, M., 2020. Behind and beyond the meter: what's in it for the system?, in: Sioshansi, F. (Ed.), Behind and beyond the meter: Digitalization, Aggregation, Optimization, Monetization. ELSEVIER ACADEMIC PRESS, [S.l.]. Reading material will be provided during the course via the e-learning platform ILIAS.
Course prerequisites
-

<table>
<tr><td colspan="4">Course
M.Sc. Environmental Governance</td></tr>
<tr><td colspan="3">Availability to other courses
M.Sc. Renewable Energy Engineering and Management</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
95996</td><td colspan="2">Module name
Introduction to Sustainability Transitions</td><td>Semester/return
3rd Sem. / annual</td></tr>
<tr><td>Workload/presence
5 ECTS-P (150h/60h)</td><td>Prerequisite module(s)
---</td><td>Follow-up module(s)
---</td><td>No. of participants
Max. 25</td></tr>
<tr><td>Teaching form
Socratic lectures, group work, presentations</td><td>Examination form
Written assignment, group work presentation</td><td>Start date
20.02.2023</td><td>Location
Hörsaal Herman-Herder-Str. 5</td></tr>
<tr><td colspan="4">Module coordinator: Prof. Dr. Dierk Bauknecht</td></tr>
<tr><td colspan="4">Additional teaching staff: Sarah Olbrich, guests tba</td></tr>
<tr><td colspan="4">Syllabus
Today we face a variety of environmental and societal challenges such as climate change or environmental pollution. These challenges are wicked problems: they are normative both in terms of problem- and solutions-defining, characterised by a high degree of complexity and uncertainty, value-laden and highly-contested, and they are context-dependent (Markard et al. 2012; Köhler et al. 2019). To solve those problems, systemic changes are necessary that alter our ways of producing and consuming, go beyond technological fixes, and include changes on multiple dimensions. This is true for a number of socio-technical systems such as the energy system.
In recent years, Sustainability Transition Studies evolved as a new research agenda and multidisciplinary research community to contribute to solving these challenges. It has two main aims: (1) gaining a better understanding of transition dynamics, and (2) generating an impact for today’s transitions in process (governance of transitions).
This seminar introduces the field of Sustainability Transitions. We will learn about main concepts and frameworks for systemic change. We will mainly use the example of the energy transition to discuss and apply theoretical insights, but other sectors and a comparison between sectors will be discussed as well. Moreover, we will evaluate in how far theory can inform and help practitioners and decision-makers to guide and govern (energy) transitions in the making.</td></tr>
<tr><td colspan="4">Learning goals and qualifications
• Getting familiar with the field of sustainability transitions
• Understanding prominent concepts and frameworks in the field of socio-technical sustainability transitions
• Applying these concepts to transitions in the making
• Evaluating on how theoretical insights can inform practitioners and policy-makers</td></tr>
<tr><td colspan="4">Course prerequisites</td></tr>
</table>

<table>
<tr><td colspan="2">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td>Availability to other courses This module is also available to students of the MSc programmes MEG, Geography, REM, Forest Sciences, and SSE.</td><td>Instruction Language
English (German speaker available</td></tr>
</table>

Module No.	**Module name**		**Semester/return**
64116	**Industrial Ecology Projekt**		3rd Sem. / annual
Workload/presence 5 ECTS-P (150h/60h)	**Prerequisite module(s)** ---	**Follow-up module(s)** ---	**No. of participants** Max. 15
Teaching form Seminars and project work	**Examination form** Term paper	**Start date** 20.02.2023	**Location** Tba.

Module coordinator: Prof.Dr. Stefan Pauliuk (stefan.pauliuk@indecol.uni-freiburg.de)

Additional teaching staff
Members of the industrial ecology group

Syllabus

This module prepares the students for conducting their master thesis in the industrial ecology group, and is reserved mostly for students who intend to do so. Its introduction consists of an overview of the main system linkages, methods, and history of industrial ecology. During the main part of the course, the students work independently on either their future master thesis topic or on another self-chosen topic that can be studied using industrial ecology methods.

Important note:

This course is mandatory for all students who wish to conduct the research for their MSc thesis in the industrial ecology group. Access restrictions apply, as students need to have successfully completed the Life Cycle Management Course. Potential participants are expected to contact the module coordinator beforehand, the deadline for applying for a master thesis in the group is Jan 20 of each year. Students who do not aim for an MSc thesis in the field of industrial ecology can also apply but will not be given priority during admission.

Content:
The goal of this course is to enable students to independently conduct quantitative research on industrial systems (industrial ecology). Participants will become familiar with the state of the art of the research on industrial systems, including material and energy flow analysis, life cycle sustainability assessment, environmental (carbon, water, land) footprinting, and integrated assessment modelling. They will learn about the central steps required for a master thesis in the field of industrial ecology, and by the end of the course, they will be able to formulate a research proposal as starting point of their MSc thesis.

Course work will include seminars and the preparation of a term paper, both under supervision by members of the industrial ecology group. The term paper is an independent scientific piece of work, which will serve as basis for the course grade. It is expected to contain a literature review with a research gap, research question (goal and scope), followed by a quantitative analysis of a sustainable development strategy. Students can work on a topic of their choice, which, as experience has shown, is their future master thesis topic in most cases.

By the end of the course, students who wish to write their thesis in the group have enough input to develop their thesis proposal (which is not part of this course).

Learning goals and qualifications

After successful completion of the course, students will have an overview of the current research topics in industrial ecology, the important actors in the field, the common scientific journals and other publication channels, and the main applications of industrial ecology research in policy making and industry.

In particular, the students will be able to:

- conduct a literature search on the quantitative analysis of specific sustainable development strategies
- critically review the literature, identify research gaps, and formulate their own research questions
- independently improve skills on and apply one the central methods of industrial systems analysis, including material flow analysis, input-output analysis, and life cycle assessment
- conduct a case study and write a scientific text in German or English that adheres to the specific writing style of the environmental systems sciences
- interact with experts on environmental and industrial systems analysis on a scientific level.

Recommended reading

- **Industrial Ecology** (2nd Edition), by Thomas E. Graedel and Braden R. Allenby, ISBN 978-0130467133, 1 copy in the library

- **Guidelines for Good Scientific Practice and Supervision in the Industrial Ecology Group in Freiburg**, Stefan Pauliuk 2016. Can be obtained from module coordinator or from this link: http://www.omnibus.uni-freiburg.de/~sp1046/Documents/ScientificWork_IndEcolFreiburg_2016.pdf

- **Input-Output Analysis: Foundations and Extensions** (2nd Edition), by Ronald E. Miller and Peter D. Blair, ISBN 978-0521739023, several copies in the library

- **Practical Handbook of material flow analysis**, by Brunner and Rechberger, ISBN 0203507207, 1 copy in the library

- **Industrial Ecology open online course:** http://www.teaching.industrialecology.uni-freiburg.de/

Course prerequisites

Participants must have participated in the *Life Cycle Management* course before taking this course.

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses ---			**Instruction Language** English
Module No. **93952**	**Module name** **Energy System Operations**		**Semester/return** 2nd Sem. / annual
Workload/presence 5 ECTS/(100h/50h)	**Prerequisite module(s)** Natural Resources and Conversion Technologies	**Follow-up module(s)** Elective modules	**No. of participants** Max. 75
Teaching form Lectures, exercises, excursion	**Examination form** Exam	**Start date** 17.04.2023	**Location** t.b.a
Module coordinator: Prof. Dr. Anke Weidlich			
Additional teaching staff:			

Syllabus

To understand the role of renewable energies for sustainable energy systems, it is essential to know how today's electricity systems work. In this module, electricity systems are discussed from the generation via the transmission and distribution to the usage of electric power. Links to other energy systems, such as natural gas supply, heating systems or mobility are reflected as well. Topics include fundamentals about the functioning of three-phase alternating current systems, along with challenges for frequency control and voltage stability in the presence of high shares of fluctuating renewable energy. Basics of markets and the specifics of electricity markets help to understand the system operation. Relevant discussions on the further development of energy systems, for example the degree of (de)centralization, the role of cross-border electricity exchange, the role of market mechanism and the available technologies for providing operational flexibility for matching demand and supply are made comprehensible by facilitating the understanding of its underlying fundamentals.

Learning goals and qualifications

The students acquire fundamental knowledge of today's electricity systems, which is essential to integrate renewable energy power supplies effectively in existing electricity systems in terms of technology, economics and sustainability. The students understand how electricity is distributed through the electricity grid and know what can be done to solve challenges in the system stability and the security of supply. They know how energy system operation is managed by the interplay of different market roles, such as transmission and distribution system operators, generating companies, power markets, and energy retailers.

Recommended reading

- Relevant literature will be given to the student in advance and also presented in the module

Course prerequisites

Content of the module "Scientific Framework for REM" and "Natural Resources and Conversion Technologies".

<table>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses
---</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
93410</td><td colspan="2">Module name
Introduction to Business Management</td><td>Semester/return
2nd Sem. / annual</td></tr>
<tr><td>Workload/presence
5 ECTS-P (150h/60 h)</td><td>Prerequisite module(s)
--</td><td>Follow-up module(s)
Management II</td><td>No. of participants
max. 75</td></tr>
<tr><td>Teaching form
Lectures, Exercises, Seminar</td><td>Examination form
Written Assignments</td><td>Start date
08.05.2023</td><td>Location
t.b.a</td></tr>
<tr><td colspan="4">Module coordinator: Dr. Roderich von Detten (r.v.detten@ife.uni-freiburg.de)</td></tr>
<tr><td colspan="4">Additional teaching staff:</td></tr>
</table>

Syllabus

1. Basics of business economics (continuation from module “scientific framework”)

Business management: business plan - entrepreneurial thinking - cost orientation - strategic decision making - process optimization - business results analysis (key performance indicatators and financial reports)

2. Basics of management:

Various topics, such as Organizational theories, Management Theories, Concepts & Instruments, Systemic Management, Strategic Management & Planning, Human Resource Management & Leadership, Marketing, Risk Management, Organization Structures & other selected topics (e.g. business ethics) will be discussed

Teaching form:

Whereas week no.1 will be dedicated to playing a computer-based business game (where different groups compete on a virtual market), week no.2 and 3 a taught in a “seminar format” i.e. via the discussions of selected readings (textbook chapters, articles or scientific publications).

In addition, the choice of an individual paper topic, the carving out of proper research questions as well as the writing process for scientific papers will be discussed during class

Learning goals and qualifications

- Knowledge of fundamental economic concepts as a basis for the application of business instruments
- Ability to apply strategic management concepts
- Additional general skills: rhetoric, discussion and presentation skills, competence for team work

Recommended reading

There are several introductions to economy:

- e.g. for management: Cole, G. a. 2003. Management. Theory and Practice. 6th edition. Cengage Learning (UK).
- e.g. for economics: Parkin, M., Powell, M. and Matthews, K. 2003 Economics, 5th Edition, Harlow: Addison-Wesley

During the module materials will be made available via the learning platform ILIAS

Course prerequisites

None.

<table>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses
---</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
93320</td><td colspan="2">Module name
Research Skills and Ethics for Sustainable Development</td><td>Semester/return
2nd Sem. / annual</td></tr>
<tr><td>Workload/presence
5 ECTS-P (150/60h)</td><td>Prerequisite module(s)
Scientific Framework for REM</td><td>Follow-up module(s)</td><td>No. of participants
max. 75</td></tr>
<tr><td>Teaching form
Lectures, Exercises, Seminar, presentations</td><td>Examination form
Written assignment: Paper summary, research proposal, ethics case study (pass or fail)</td><td>Start date
05.06.2023</td><td>Location
t.b.a</td></tr>
<tr><td colspan="4">Module coordinator: Jun-Prof. Cathrin Zengerling, e-mail: cathrin.zengerling@enrlaw.uni-freiburg.de</td></tr>
<tr><td colspan="4">Additional teaching staff: Philipp Thapa, Johan Velez</td></tr>
<tr><td colspan="4">Syllabus
This module is the final course of the compulsory part of the REM programme. It deals with the introduction of sciences and scientific methodology. There are no prerequisites required for this course. In the first part of the module, students will be familiarized with the process of research including research strategy and cycle, literature review but also scientific misconducts and fraud. Students will get familiar with scientific citation and bibliography. A knowledge synthesis of a relevant scientific paper of medium complexity will be written and graded.

In the second part of the module, students will learn the main goals and methods of qualitative and quantitative research process. This part includes details about research design, data collection and data analysis, as well as preparation for scientific communication and scientific publications, such as writing papers, presenting posters, etc. An own research proposal will be written and graded.

The ethics part of the module adds a normative and utopian perspective to the idea of socio-metabolic transitions. The focal double question is: “What future do we want, and why?” Students develop awareness for the diversity both of possible future visions and of the reasons and criteria that can be used to support or criticise their pursuance. They learn to distinguish between factual claims and normative appeals and to analyse their intertwinement in concepts such as development, economic growth, sustainability, biodiversity, or nature. They practise making normative arguments of their own and questioning those of others. Together, we discuss the main conceptions of sustainability and ethics and offer an introduction into environmental ethics, including the question whether we owe respect to (some) non-human beings. Students learn to consider “social technologies”, including ethics and lifestyles, as potential tools for sustainable development in addition to engineering solutions. (Main responsibility: Philipp Thapa)</td></tr>
<tr><td colspan="4">Learning goals and qualifications
• Students will be able to understand the main goals and common methods of qualitative and quantitative research (including empirical methods and statistics)
• Students will be able to develop meaningful research questions (hypothesis) and to design studies to evaluate their hypothesis (including research design, data collection and analysis)</td></tr>
</table>

- Students will be able to communicate their research results among scientific community via scientific texts
- Scientific synthesis and writing skills, overview of research skills and application of research skills for development of research proposal (knowledge synthesis and research gap, method choice and description, description of expected results and discussion items)
- Detailed knowledge about environmental ethics
- Awareness of the ethical aspects of sustainable development
- Basic knowledge of the main ethical approaches and normative argumentation skills

Recommended reading

Curd, M. and Cover, J. A (1998): Philosophy of science - the central issue. W. W. Norton & Company, New York

McCaskill, M. K. (1998): Grammar, punctuation and capitalization: A handbook for technical writers and editors (NASA SP-7084). Langley Research Centre, Hampton, Virginia

Popper, Karl (2004): The logic of scientific discovery. London: Routledge-Classic

Strauss, A. and Corbin, J. (1990): Basics of qualitative research: Grounded theory procedures and techniques. Sage Publications

Ott, Konrad: Essential components of Future Ethics. In: Döring, Ralph / Rühs, Michael (eds.): Ökonomische Rationalität und praktische Vernunft. P. 83-108.

Note: All reading is provided as pdf on the University's online learning platform ILIAS.

Course prerequisites

None

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses ---			**Instruction Language** English
Module No. **93935**	**Module name** **Elective Hydropower**		**Semester/return** 2^{nd} Sem. / annual
Workload/presence 5 ECTS-P (150/60h)	**Prerequisite module(s)** "Natural Resources and Conversion Technologies"	**Follow-up module(s)** ---	**No. of participants** Max. 35
Teaching form	**Examination form** Exercises and project work (short essay)	**Start date** 26.06.2023	**Location** t.b.a.
Module coordinators: Prof. Dr. Markus Weiler			
Additional teaching staff: Dr. Andreas Hänsler			

Syllabus

- In depth look at the water cycle and especially the runoff producing mechanisms in different parts and climates around the world using climate and hydrologic data from different locations.
- Example calculations showing the assessment of the potential of water power generation from basic hydrological river data.
- Detailed look at the design and cost of different types of water power projects.
- Detailed look at the economic balance of hydropower projects (investment and running cost vs. return from generating and selling electricity). Potential, probability, and risk of designing economically viable hydropower projects using real life examples and theoretical excercises.
- Consideration and mitigation strategies of social, environmental, and economic problems associated with hydropower projects.
- Several field day trips to different types of hydropower operations around southern Germany and Switzerland.
- Software used will include simple hydrologic models like "HBV", and spreadsheet/statistic software like EXCEL / R / and/or MATLAB

Learning goals and qualifications

- Improved understanding of the underlying hydrological processes leading to river runoff in different parts of the world.
- Improved understanding of hydropower plants and their usefulness for different purposes and river types.
- Better awareness of the economic advantages and possibilities as well as the potential disadvantages and dangers of planning and building hydropower plants.
- Better understanding of negative impacts of hydropower on the environment and society and how to avoid or mitigate these effects.

Recommended reading

- Handbook of Hydrology, Chapters: 5, 8, 9, 17, 18, 19, 21, 27.
- IHA 2015 Hydropower Status Report
- World Commission on Dams (2000): Dams and Development: A new Framework for Decision-Making

Course prerequisites

Course

M.Sc. Renewable Energy Engineering and Management			
Availability to other courses ---			**Instruction Language** English
Module No. **97014**	**Module name** **Solar Thermal Energy 1**		**Semester/return** 3rd Sem. / annual
Workload/presence 5 ECTS (150 h/60 h)	**Prerequisite module(s)** Natural Resources and Conversion Technologies	**Follow-up module(s)** Solar Thermal Energy 2	**No. of participants** Max. 25
Teaching form Lectures, Exercises, Excursion (depending on students numbers)	**Examination form** Written Exam	**Start date** 26.06.2023	**Location** University of Freiburg Fraunhofer ISE
Module coordinator: Prof. Dr. Werner Platzer			
Additional teaching staff: Dr. Korbinian Kramer, Dr. Manuel Lämmle,			

Syllabus

In this module the students will learn the basic knowledge about low and high-temperature solar thermal energy applications and combinations with energy efficiency measures in buildings. The module includes basic theory and technology know –how as well as all different STE applications:
- Market overview
- Solar resources and technical availability
- Demand profiles for domestic hot water, solar assisted heating, preheating of air; industrial heat

- Active and passive solar collector concepts and components (flat-plate, vacuum-tube, concentrating collectors, windows, etc.)
- Collector design, materials and technology
- Performance parameterisation and technical characterisation e.g. efficiency determination, IAM, function test, accelerated aging, quality assurance
– Thermal storage concepts (sensible short term and seasonal storage)
- System design concepts for small and large solar thermal systems (performance and economics - Integration of solar thermal heat into industrial processes
- Concentrated solar thermal power (CSP): Solar field concepts, system aspects
- Solar cooling and desalination projects
- Project planning, financing and implementation for CSP and solar process heat
- Economical assessment and financing options

Learning goals and qualifications

In this course, students will learn about the use of solar thermal systems, components used and specifications with respect to many applications from heating water, heating of buildings to industrial process heat and solar thermal electricity. They will learn temperature and efficiency limitations, how to improve thermal systems by specific material design and selection. System analysis with respect to storage concepts, hydraulic flow regimes and flow control will be intensified. Students will be able afterwards to discuss designs for solar systems with normal and concentrating collectors, perform simulations and assess the performance and economics of projects. The students will understand the interrelations between system components know different system concepts and calculate the solar gains of different systems. They can understand the role of low and high temperature solar thermal energy conversion in the energy system.

Recommended reading

Duffie, J. A., Beckman, W., Blair, N., Solar Engineering of Thermal Processes, Photovoltaics and Wind, 5th Edition, Wiley, 2020
Lovegrove, K., Stein, W. (Eds.): Concentrating Solar Power Technology, 2nd Edition, Woodhead/Elsevier, 2020
Cabeza, L. (Ed.), Advances in Thermal Energy Storage Systems, 2nd Edition, Woodhead/Elsevier, 2020

Course prerequisites

“Natural Resources and Conversion Technologies - Solar Thermal Energy”

- Basic knowledge of solar thermal systems and solar radiation calculation
- Knowledge of heat transfer mechanisms (radiation, convection)
- Knowledge of thermodynamic cycles (heat pumps, heat engines)

<table>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses This module is offered as elective to the MSc programmes MEG, MSc. Geographie des Globalen Wandels; MSc. Environmental Sciences</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
93936</td><td colspan="2">Module name
Global Sustainability Transformations in Local Contexts</td><td>Semester/return
3rd Sem. / annual</td></tr>
<tr><td>Workload/presence
5 ECTS-P (150h/60h)</td><td>Prerequisite module(s)
---</td><td>Follow-up module(s)
---</td><td>No. of participants
Max. 25</td></tr>
<tr><td>Teaching form
Lectures, group work, presentations</td><td>Examination form
Essay (indiv., 2000 words), case study (group, 3000 w)ords, present. (group, 15 min.)</td><td>Start date
26.06.2023</td><td>Location
Tba.</td></tr>
<tr><td colspan="4">Module coordinator: Jun.-Prof. Dr. Cathrin Zengerling, Dr. Benedikt Schmid</td></tr>
<tr><td colspan="4">Additional teaching staff
Guests tba</td></tr>
<tr><td colspan="4">Syllabus

Cities consume about 75% of global energy and material flows and are home to more than half of the global population – with a rising tendency. They are an increasingly visible actor in emerging polycentric environmental governance, engage in international legal regimes such as the Paris Agreement and transnational municipal networks (TMNs). Infrastructures and lifestyles in local systems are crucial for people's well-being within planetary boundaries. Many processes of sustainability transformations around energy, mobility, food, housing, and consumer goods are rooted in local systems. They offer room for experiments and niches and allow for first steps in diffusion and upscaling. Local governments can be closer to people and more responsive to specific local needs and conditions than higher levels of government. Local economies play a key role in value creation and capture.

In this module, students learn about cities and municipalities as actors in an emerging system of polycentric environmental governance. They gain knowledge on the role of local governments within the Paris Agreement, TMNs as well as national state hierarchies in different legal systems and the respective local scope of action. We explore different modes of governing processes of transformation across different sectors (energy, mobility, food, housing and others) as well as scales (neighbourhood, city, translocal) in international case studies in the global north and south. The key forms of local decision-making (including referendums), formal as well as informal steering instruments including land use plans, urban development contracts and climate action plans are introduced. Students also get insights into the relationship and forms of cooperation between urban and (surrounding) rural areas in the context of the (energy) transition. With regard to local and community economies, students learn about (re)municipalisation, eco-social enterprises and community initiatives. We discuss alternative forms of ownership such as cooperatives and sharing schemes, in particular in the context of alternative economies and degrowth.

The course is taught in an interactive manner. We will kick off our joint work with an explorative zero carbon walk in a Freiburg neighbourhood. Throughout the course, we present and discuss international case studies and students get the chance to deepen their knowledge in their main fields of interest. The course also encompasses an excursion to the new low carbon urban development project Dietenbach and discussions with representatives of the urban planning department.</td></tr>
</table>

Learning goals and qualifications

In this module students:

- develop a critical understanding of contemporary processes of urban sustainability transformations with a main focus on the sectors of energy, mobility, housing and food,
- understand the role of cities in emerging polycentric environmental governance, varying local scopes of action and key formal and informal steering instruments of urban governance
- discuss and reflect upon the role of law and planning in urban sustainability transformations,
- analyse academic publications, legal and policy documents and other planning-related materials,
- apply their knowledge to case studies of contemporary urban transformation processes in their field of interest
- compare, contrast and transfer their knowledge to other cases.

Classification of cognitive skills following Anderson & Bloom (2001):

1 = *Remember*: retrieving relevant knowledge from long term memory; 2 = *Understand*: determining the meaning of instructional messages (interpreting, exemplifying, summarizing ...); 3 = *Apply*: carrying out or using a procedure in a given situation; 4 = *Analyze*: breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose; 5 = *Evaluate*: making judgment based on criteria and standards; 6 = *Create*: putting elements together to form a novel, coherent whole or make an original product.

Recommended reading

Kraas, F., Leggewie, C., Lemke, P., Matthies, E., Messner, D., Nakicenovic, N., ... & Butsch, C. (2016). *Humanity on the move: Unlocking the transformative power of cities*. WBGU-German Advisory Council on Global Change.

Reading material will be provided during the course via the e-learning platform ILIAS.

Course prerequisites

-

<table>
<tr><td>Module number
94298</td><td colspan="2">Module name
Elective: Leadership and Social Entrepreneurship</td></tr>
<tr><td>Course of study
MSc Environmental Governance</td><td>Type of course
Elective module</td><td>Semester / Rotation
2nd / Summer Term</td></tr>
<tr><td>Teaching methods
lectures, group work</td><td>Prerequisites for attendance
None</td><td>Language
English</td></tr>
<tr><td colspan="2">Type of examination (Final Grade Composition)
PL Group and individual presentations (20%)
PL Written group essay (40%), ca. 5000 words
PL Written individual essay (40%), ca. 2000 words</td><td>ECTS-LP (Workload)
5 (150h, of this 60 contact hrs.)</td></tr>
<tr><td colspan="2">Module coordinator
Prof. Dr. H. Schanz, e-mail: heiner.schanz@envgov.uni-freiburg.de</td><td>SWS
4</td></tr>
<tr><td colspan="3">Additional teachers involved
Barbara Börner (social entrepreneurship and sustainability consultant); Björn Adam (business law, systemic management and coaching)</td></tr>
<tr><td colspan="3">Syllabus
While environmental governance is often associated with governments, it also takes into account the role of other stakeholders that have an impact on the environment, including the private sector, NGOs and civil society. This module will deal with two prominent approaches in the field of environmental governance: (i) (environmental) leadership, particularly beyond governments, and (ii) social entrepreneurship.
(i) Recent research shows that environmental leadership is often viewed as an “unequivocal good” and important for effective environmental governance; however, these assumptions are rarely critically discussed and empirically tested (Evans et al. 2015). (Environmental) leadership remains a broad, multi-faceted and contested concept. We will review theories of leadership in order to understand what it takes to be a leader, what leaders do, where leaders come from, how leaders interact with their social environment and their followers, how leadership develops, and how specifically leadership shapes environmental and sustainability governance. The students will apply various approaches to leadership to specific case studies in order to explore the role of leaders and leadership in concrete organizations and contexts.
(ii) The concept of Social Entrepreneurship addresses social and ecological challenges that are unmet by private markets or governments; it is motivated primarily by generating earned income to serve a social mission, or by the role of innovation in creating social change. In this course, the key tenets of social entrepreneurship are discussed and exemplified by specific “business cases.” In the practical part of the course, students will evaluate real-world start-up social enterprises via small “consultancy projects.” Students will conduct business case studies and present their evaluations to the class.
The module also includes a one-day study trip to RegionalWert A.G., a social enterprise and a citizen shareholder society that supports sustainable regional agriculture and food economy in the Freiburg area by linking citizen investors and sustainable enterprises.</td></tr>
<tr><td colspan="3">Learning goals and qualifications
In this module students learn to:
– understand and critically assess different approaches to (environmental) leadership and social entrepreneurship (1, 2);</td></tr>
</table>

- evaluate the role of leaders and leadership in environmental governance processes (5);
- compare the perspectives, strengths and weaknesses of different approaches (4);
- apply theoretical approaches to current issues and specific cases of leadership and social entrepreneurship (3); and
- evaluate how theoretical approaches to social entrepreneurship work in practice (5).

Classification of cognitive skills following Bloom (1956):

1 = *Knowledge*: recalling facts, terms, basic concepts and answers; 2 = *Comprehension*: understanding something; 3 = *Application*: using a general concept to solve problems in a particular situation; 4 = *Analysis*: breaking something down into its parts; 5 = *Synthesis*: creating something new by putting parts of different ideas together to make a whole; 6 = *Evaluation*: judging the value of material or methods.

Core readings

A list of relevant texts will be made available at the start of the course; obligatory readings (and part of the voluntary readings) will be made available online in electronic form. The following are some preliminary readings.

Zeyen, A., M. Beckmann and R. Akhavan. 2013. Social Entrepreneurship Business Models: Managing Innovation for Social and Economic Value Creation. In: Managementperspektiven für die Zivilgesellschaft des 21. Jahrhunderts. Management als Liberal Art. Wiesbaden: Springer Gabler.

Mair, J. 2010. Social Entrepreneurship: Taking Stock and Looking Ahead. In: A. Fayolle and H.

Matlay, eds. Handbook of Research on Social Entrepreneurship, Edward Elgar: Cheltenham, Chapter 2.

Stephan, U. et. al. 2016. Organizations Driving Positive Social Change. A Review and an Integrative Framework of Change Processes. Journal of Management 42 (5), 1250 –1281.

Evans, Louisa S. et al. 2015. Understanding leadership in the environmental sciences. Ecology and Society 20(1): Art. 50

Gallagher, Deborah R., ed. 2012. Environmental leadership. Los Angeles: Sage

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses ---			**Instruction Language** English
Module No. **93931**	**Module name** **Elective Bioenergy**		**Semester/return** 2nd Sem. / annual
Workload/presence 5 ECTS-P (150 / 60h)	**Prerequisite module(s)** Natural Resources and Conversion Technologies	**Follow-up module(s)** -	**No. of participants** Max. 40
Teaching form Online Lectures, group discussions	**Examination form** Written Report and Presentation	**Start date** 17.07.2023	**Location** T.b.a.

Module coordinator: Dr. Sebastian Paczkowski

Additional teaching staff:

Syllabus

The module will introduce the most relevant energy conversion technologies related to municipal and industrial waste products, non-woody and woody biomass. In addition, aspects of production/abundance, harvesting, logistic, and storage of non-woody and woody biomass, as well as municipal and industrial waste will be addressed.

Chemical engineering aspects of conversion processes such as:

- torrefaction, pyrolysis
- gasification, BtL
- combustion
- biogas
- biodiesel
- bioethanol

are given in the frame of the module.

Advantages and disadvantages of these processes will be discussed in terms of biomass resources, production technology, product characteristics, and emissions.
A group work that comprises a management and technology concept for a selected place/technology will allow the students to apply their knowledge and to investigate their project's feasibility.

Learning goals and qualifications

The students will learn fundamental concepts of conversion processes for municipal and industrial waste, non-woody and woody biomass. They will also get a basic understanding of related technologies, e.g. harvesting, transport and storage. They will be able to assess different technologies with respect to strengths and weaknesses.

Furthermore, the students will learn to assess the potentials of waste / biomass production and logistics.

The students will practice how to apply essential information in a management process and to present the results in written and oral form.

Recommended reading

Specific literature will be recommended in the module.

Course prerequisites

The module "Natural Resources and Conversion Technologies" is a prerequisite.

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses ----			**Instruction Language** English
Module No. 93933	**Module name** **Elective Wind energy**		**Semester/return** 2nd Sem. / annual
Workload/presence 5 ECTS-P (150h/60h)	**Prerequisite module(s)** Elective I	**Follow-up module(s)** ---	**No. of participants** Max. 30
Teaching form Online/pre-recorded lectures, exercises, question times	**Examination form** Poster presentation	**Start date** 17.07.2023	**Locations** T.b.a.

Module coordinator: Prof. Dr. Dirk Schindler (dirk.schindler@meteo.uni-freiburg.de)

Additional teaching staff: Balázs Garamszegi

Syllabus

The wind energy module provides students with a deep understanding of the meteorological, geographical and technical wind energy potential with supplementary information on the economic and implementation potential. The module structure is basically project-oriented including lectures, GIS, and modeling exercises.

In the module the following topics will be discussed:

- Basics of wind resource characteristics at different spatiotemporal scales
- Wind speed and wind direction statistics including distribution fitting
- Influence of surface characteristics on the wind resource
- Aspects of power curves and repowering
- Economics of wind energy
- Integration of wind energy into the electricity grid
- CO_2 emission mitigation potential of wind energy, wind-to-gas potential

Learning goals and qualifications

- Understanding of wind characteristics and their state-of-the-art statistical description.
- Understanding of how the wind resource can best be used by existing technology.
- Students will be enabled to develop wind turbine siting strategies for maximizing wind energy yield..

Recommended reading

Grau, L., Jung, C., Schindler, D., 2017: On the Annual Cycle of Meteorological and Geographical Potential of Wind Energy: A Case Study from Southwest Germany. Sustainability 9, 1169.

Jung, C., Schindler, D., Laible, J., 2018: National and global wind resource assessment under six wind turbine installation scenarios. Energy Conversion and Management 156, 403-415.

Manwell, J.F., McGowan J.G., Rogers, A.L., 2009: Wind energy explained: theory, design and application. Chichester, Wiley.

Course prerequisites

Basic knowledge of wind energy.

Modul / *Module*
Energy in Buildings: energy demand and building physics

Nummer: *Number*	11LE68MO-4112		
Modulverantwortlicher: *Responsible person*	Prof. Dr. H.-M. Henning, Dr. S. Hess, B. Rodenbücher, R. Eberle	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	lecture and practical exercise	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Energy Storage, Solar Energy		
Zwingende Voraussetzungen: *Mandatory requirements*	none		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS credits*	6
SWS: *Semester week hours*	4	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	180 hours (total incl. preparation and lecture attendance)		

Lernziele / *Learning objectives*
The students know the influencing factors on the energy demand of buildings. They know about the requirements and prerequisites for low energy and passive houses. They are familiar with methods for setting up energy balances for buildings and the relevant technical indoor equipment. Students are able to judge under which circumstances zero-energy or plus-energy buildings (with respect to the annual primary energy balance) are attainable. They know the requirements and criteria for indoor comfort in buildings and they are able to estimate the influence of different renovation and retrofit measures on the energy demand and indoor comfort. They know use cases and limits of different heat transfer systems for heating and cooling of indoor environments and are familiar with low exergy concepts for building energy systems.

Inhalte Vorlesung / *Content of the lecture*
• Selected chapters of building physics regarding energy demand of buildings for heating and cooling • Indoor comfort in buildings • Ventilation demand and ventilation concepts • The passive house concept • Passive use of solar energy in buildings; physics of transparent building components • Passive systems / concepts for cooling of buildings • Exergetic evaluation of building systems • Heat transfer systems to rooms for heating and cooling • Efficient energy conversion chains, „low-ex“ systems

Inhalte Praktische Übung / *Content of the practical exercise*
The lecture will be accompanied by a weekly exercise to deepen the understanding of the lecture's content and to discuss further details. The practical exercise includes calculations, practical experiments (e.g. on thermal insulation and optical properties), system simulations (with polysun) and/or case studies.

Zu erbringende Prüfungsleistung / *Course-based assessment*
Written supervised exam

Zu erbringende Studienleistung / *Coursework*
Attendance during the practical exercise is required (minimum 85 % attendance). Work on (weekly) exercise sheet and written documentation.

Literatur / *Literature*
Energy Performance of Buildings - Energy Efficiency and Built Environment in Temperate Climates. Editors: Boemi, Sofia-Natalia, Irulegi, Olatz, Santamouris, Mattheos (Eds.). Springer. ISBN 978-3-319-20831-2

<table>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses
---</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
6900</td><td colspan="2">Module name
Internship (Praktikum)</td><td>Semester/return
2nd - 3rd Sem. / annual</td></tr>
<tr><td>Workload/presence
10 ECTS-P (300 h)</td><td>Prerequisite module(s)
---</td><td>Follow-up module(s)
---</td><td>No. of participants
max. 75</td></tr>
<tr><td>Teaching form
Practical work</td><td>Examination form
Written report</td><td>Start date
07.08.2023</td><td>Location
t.b.a.</td></tr>
<tr><td colspan="4">Module coordinators: Prof. Dr. Stefan Pauliuk (stefan.pauliuk@indecol.uni-freiburg.de)</td></tr>
<tr><td colspan="4">Additional teaching staff
Academic experts of the respective internship institution</td></tr>
<tr><td colspan="4">Syllabus
The MSc. programmes at the Faculty of Environment and Natural Resources Freiburg as a rule include a practical training in accordance with the examination regulations for the degree programme Master of Science. The practical training is completed in institutions and companies outside the faculty or in research departments of the ZEE and his partners.
Possible internship providers include:
▪ Renewable energy and power supply companies
▪ Planning and Engineering companies
▪ Consultancy and information services (energy agencies, technology transfer institutions) and public relation
▪ Science and research dealing with renewable energies
▪ Financing and Investment companies specialising in financing environmental projects, as well as investment and development banks</td></tr>
<tr><td colspan="4">Learning goals and qualifications
The internship provides students with a first insight into potential employment sectors; in all sectors this is primarily achieved by practical work. Apart from gaining an overview of the subject, students should experience typical work processes and the human interactions in an organization. The assigned work gives students an idea of the daily work procedure at their workplace (‘everyday life experiences’). Additionally, students become familiar with the structures within the institution, as well as the interconnections with external systems.
Furthermore, the expert knowledge gained in the course of the studies is intensified and to a certain degree, applied during the practical training.</td></tr>
<tr><td colspan="4">Recommended reading
None.</td></tr>
<tr><td colspan="4">Course prerequisites
None.</td></tr>
</table>