Module handbook

REM M.Sc. Renewable Energy Engineering and Management

Academic year 2017/2018

State of 14.11.2017

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 2017/18 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="4">January</td><td colspan="4">February</td><td colspan="5">March</td><td></td></tr>
<tr><td>CW</td><td></td><td></td><td></td><td>42</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/ 52</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>13</td><td>CW</td></tr>
<tr><td></td><td colspan="3">13.10.</td><td colspan="9">16.10 – 15.12.</td><td colspan="2">- 5.01.</td><td colspan="3">08.01–26.01.</td><td colspan="3">29.01. – 16.02.</td><td colspan="3">19.02. – 09.03.</td><td colspan="3"></td><td></td></tr>
<tr><td rowspan="4">REM (1st Sem.)</td><td colspan="3" rowspan="4">Introductionary day</td><td colspan="9">Module
Energy & Sustainable Development</td><td colspan="2" rowspan="4">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="4">REM (1st Sem.)</td></tr>
<tr><td colspan="9">Pauliuk</td></tr>
<tr><td colspan="9">Module
Scientific Framework for REM</td></tr>
<tr><td colspan="9">Pauliuk</td><td colspan="6">Pauliuk</td><td colspan="3">Ragwitz</td></tr>
</table>

	Summer term 2018 – Second Semester							
		April	May		June		July	August
CW		15 16 17	18 19 20	21	22 23 24	25 26 27	28 29 30	31 32 33 ...
		09.04 –27.04.	30.04- 18.05.	21.5-25.5	28.05. - 15.06.	18.06 – 06.07.	09.07 - 27.07.	30.07 -
REM (2nd Sem.)		Module **Generation and Distribution of Energy**	Module **Manage-ment I**	**Pentecoast Break**	Module **Society & Economy**	Module **Research Skills**	Module **Elective Bioenergy I, Wind energy**	Module **Internship**
		Weidlich	**von Detten**		**Baumgärtner**	**Pauliuk**	**Suchomel., Ragwitz**	**Pauliuk**

	Winter term 2017/18Third 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 13	CW
		16.10 – 03.11.	06.11. - 24.11.	27.11. – 15.12.	- 5.01.	08.01–26.01.	29.01. – 16.02.	19.02. – 09.03.		
REM (3rd Sem.)		Module Internship	Modules Elective Tracks	Modules Elective Tracks	Christmas Break	Modules Elective Tracks	Modules Elective Tracks	Module Project		REM (3rd Sem.)
			Energy Systems Hardware and Control	**Smart Grids**		**Energy Efficiency**	**Energy Informatics**			
			Photovoltaics 1	**Low Temperature Solar Thermal Energy**		**Photovoltaics 2**	**High Temperature Solar Thermal Energy**			
			Management 2	**Landscape, Nature Protection, Landuse Conflicts**		**Life Cycle Management**	**Bioenergy 2**			
		Pauliuk	**Diehl** **Wittwer** **von Detten**	**Wittwer** **Platzer** **Koch**		**Reindl** **Wittwer** **Pauliuk**	**Thiemann** **Platzer** **Suchomel**	**Pauliuk**		

3. Module descriptions

3.1. Winter term 2017/2018 – first semester

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

3.2. Winter term 2017/2018 – third semester

- **Internship**
- **Elective Track "Energy Systems Technology"**
  - ❖ **Energy Systems Hardware and Control**
  - ❖ **Smart Grids**
  - ❖ **Energy Efficiency**
  - ❖ **Energy Informatics**
- **Elective Track "Energy Conversion"**
  - ❖ **Photovoltaics 1**
  - ❖ **Low Temperature Solar Thermal Energy**
  - ❖ **Photovoltaics 2**
  - ❖ **High Temperature Solar Thermal Energy**
- **Elective Track "Environmental Planning and Management"**
  - ❖ **Management 2**
  - ❖ **Landscape, Nature Protection, Landuse conflicts**
  - ❖ **Life Cycle Management**
  - ❖ **Bioenergy 2**
- **Project**

3.3. Summer term 2018 – second semester

- **Generation and Distribution of Energy**
- **Management I**
- **Society and Economy**
- **Research Skills**
- **Elective Bioenergy I**
- **Elective Wind Energy**
- **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 (60%), written exam (40%)</td><td>Start date
16.10.2017</td><td>Location
tba</td></tr>
<tr><td colspan="4">Module coordinator: Stefan Pauliuk, PhD (stefan.pauliuk@indecol.uni-freiburg.de)</td></tr>
<tr><td colspan="4">Additional teaching staff
Prof. Dr. Ernst Ulrich von Weizsäcker, Philipp Thapa</td></tr>
</table>

Syllabus

The module is divided into four consecutive 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.

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.

The third 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.

In the fourth and last part of the course, students are required to form small groups and select one of the many aspects of and options related to renewable energy supply. Each group will prepare a scientific blog entry of not more than 2000 words and max. 3 figures/tables on their selected topic. This homework will be graded and texts of sufficiently high quality will be put online.

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, small student groups (2-3) 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 of renewable energy conversion and use, energy efficiency, energy policy, environmental ethics, 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
- Awareness of the ethical aspects of sustainable development
- Basic knowledge of the main ethical approaches and normative argumentation skills
- 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)

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

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.

<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.
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 exam</td><td>Start date
16.10.2017</td><td>Location
tba</td></tr>
<tr><td colspan="4">Module coordinator: Stefan Pauliuk, PhD (stefan.pauliuk@indecol.uni-freiburg.de)</td></tr>
<tr><td colspan="4">Additional teaching staff:, Prof. Dr. Oliver Ambacher, Christoph Bohnert, Dr. Roderich von Detten, Kathrin Drozella, Dr. Oswald Prucker, Dr. Michael Henze, Dr. Adnan Yousaf</td></tr>
</table>

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: Classical & modern theories & approaches of Organization & Management, Context of Management (interactions between firms and the business environment), Strategic Aspects of Management; Organisation Structures and Processes; Decision Making in organizations

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.

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 prepares students for the "Society & Economy" module which 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.
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 **-**

<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 exam</td><td>Start date
08.01.2018</td><td>Location
tba</td></tr>
<tr><td colspan="4">Module coordinator: Stefan Pauliuk, PhD (stefan.pauliuk@indecol.uni-freiburg.de)
Stefan Pauliuk, PhD (stefan.pauliuk@indecol.uni-freiburg.de)</td></tr>
<tr><td colspan="4">Additional teaching staff
PD Dr. Dirk Schindler (solar radiation & wind), Prof. Dr. Werner Platzer (solar thermal, solar power), Dr. Ralf Preu (photovoltaics), Stefan Baehr (wind energy), Prof. Dr. Markus Weiler (water & hydropower), Wenzel (geothermics & geothermal energy), Dr. Sebastian Paczkowski (biomass & bioenergy)</td></tr>
</table>

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 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, river ecology scientific discussion on dams (Internet: Hydro Association), aspects of hydropower economics, sustainable management of hydropower and case studies around the world. Hydropower as subject in the German EEG will be introduced as a model.

4. Geothermics & Geothermal Energy (1 week)

The potential of geothermal energy conversion is addressed, particularly of geothermal energy resources (Bucher): earth's thermal regime, energy budget of the earth, heat storage, heat transport, hot water in the heat reservoirs, hydraulic properties of fractured hard rock, geothermal potentials (distribution and assessment), geothermal energy resources

5. 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 understand the working principles of photovoltaics. They will understand 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 different optical and electrical loss 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. Finally they will get insight into cost issues and scenarios for the different technologies.

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 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. Geothermics & Geothermal Energy (1 week)

The students acquire basic knowledge about the physics of the earth, the principles concepts of using geothermal energy, the technologies, the applications, the challenges as well as the solution strategies for geothermal energy conversion. They know how to evaluate potential of geothermal energy conversion at given local conditions with respect to sustainability and economics.

5. 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 test + group work presentations</td><td>Start date
19.02.2018</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>
</table>

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.

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. **6900**	**Module name** **Internship (Praktikum)**		**Semester/return** 2nd - 3rd Sem. / annual
Workload/presence 10 ECTS-P (300 h)	**Prerequisite module(s)** ---	**Follow-up module(s)** ---	**No. of participants** max. 75
Teaching form Practical work	**Examination form** Written report	**Start date** 14.08.2017	**Location** t.b.a.

Module coordinators: Stefan Pauliuk, PhD (stefan.pauliuk@indecol.uni-freiburg.de)

Additional teaching staff

Academic experts of the respective internship institution

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

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.

Recommended reading

None.

Course prerequisites

None.

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses ---			**Instruction Language** English
Module No. **97000**	**Module name** **Energy Systems Hardware and Control**		**Semester/return** 3rd Sem. / annual
Workload/presence 5 ECTS (150 h / 60 h)	**Prerequisite module(s)**	**Follow-up module(s)** Generation and distribution of energy	**No. of participants** Max. 25
Teaching form Lectures and Exercises	**Examination form** Written exam	**Start date** 06.11.2017	**Location** University Freiburg
Module coordinator: Prof. Moritz Diehl (moritz.diehl@imtek.uni-freiburg.de)			
Additional teaching staff PD Rüdiger Quay (ruediger.quay@iaf.fraunhofer.de), Dr. Michael Erhard			

Syllabus

In this module the students will learn about high power electronics with a particular emphasis on control.

The compact course is split in two parts:

- A) The hardware of high-power electronics
- B) Systems Theory and Feedback Control

In Part A of this module building hardware aspects of power electronics will be introduced. The course starts with the fundamentals and concepts of power devices and circuits. It comprises three aspects: fundamental power conversion-concepts with focus on DC-DC and –AC conversion, more complex power circuitry, and actual power conversion systems. At the interface of modern electronics, circuit design, and control theory, advanced analysis and characterisation techniques are introduced in order to bridge the gap from modern power conversion to the understanding of systems and network systems with all aspects of power conversion. Students will carry out study examples using the simulation software QUCS.

In Part B of this module, students are introduced to the design and analysis of feedback control systems. We start with regarding general ordinary differential equations (ODE) and then focus on linear time invariant systems in continuous time. Conditions for stability are discussed, and performance measures for feedback control systems defined. We then discuss state space control design in more detail, covering topics such as Luenberger Observer, Kalman Filter, the Linear Quadratic Regulator (LQR) and Model Predictive Control (MPC).

Learning goals and qualifications

In Part A, the students will be enabled to understand materials, concepts, functioning, and design of modern power devices, circuits, and converter systems. This includes the understanding of basic concepts of power conversion (AC theory), of passive and active semiconductor devices, high-voltage operation, converter-, and control concepts, device protection, and aspects of system and power network theory. The students will be competent to analyse and design passive and active power devices such as MOSFET, Insulated Gate Bipolar IGBT, and thyristors, and circuits, full converter functions, integration, and analyze full system concepts. Circuits and system concepts for power conversion, such as half and full bridges, aspects high voltage operation, and design for robustness are presented, and several examples are discussed in detail.

In Part B the students will learn how to mathematically model a given dynamical system with control inputs and sensor outputs in form of ordinary differential equation models, and how use state space estimation and control techniques to design suitable feedback controllers.

Recommended reading Everything provided in lecture and exercise.
Course prerequisites Undergraduate mathematics (calculus, linear algebra) and basics in systems theory.
Additional information Electronic manuscripts are provided for the lecture. Visit to Fraunhofer IAF

Course

M.Sc. Renewable Energy Engineering and Management

Availability to other courses			**Instruction Language**
---			English
Module No. 97001	**Module name** Smart Grids		**Semester/return** 3rd Sem. / annual
Workload/presence 5 ECTS (150 h/60 h)	**Prerequisite module(s)**	**Follow-up module(s)**	**No. of participants** Max. 25
Teaching form Lectures, Exercises, Seminar, lab experiments	**Examination form** Written exam	**Start date** 27.11.2017	**Location** 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: “Generation and Distribution of Energy”

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses ---			**Instruction Language** English
Module No. **97002**	**Module name** **Energy Efficiency**		**Semester/return** 3rd Sem. / annual
Workload/presence 5 ECTS (150 h/60 h)	**Prerequisite module(s)**	**Follow-up module(s)** Elective II Energy Efficiency	**No. of participants** Max. 25
Teaching form Lectures, Exercises, Seminar, lab experiments	**Examination form** Lab Report, Case Study, Assignments and Oral Presentation	**Start date** 08.01.2018	**Location** Uni Freiburg University of Applied Sciences Offenburg
Module coordinator: Prof. Dr. Leo Reindl (reindl@imtek.uni-freiburg.de)			
Additional teaching staff Prof. Elmar Bollin (bollin@hs-offenburg.de), Prof. Dr. Dipl.-Ing. Doreen Kalz			

Syllabus

In this module the students will learn about general aspects of energy efficiency technologies in buildings.

The compact course is split in two parts:

- Building Automation
- Building and HVAC Concepts

In Part 1 of this module building automation will be introduced as an important tool to analyse building energy performance and to operate building technologies by means of advanced building automation tools like remote control and weather forecasting. Basics of control technics including PID Controller will be introduced.

At Hochschule Offenburg students will operate different trails on building automation for the case of a realistic sized air conditioning unit. By setting the controller students are forced to go in detail with Building Automation Technologies and discuss the energy saving potentials by optimization. In a written lab report the students will summarise their learning outcomes and present the trails result.

In Part 2 of this module, students are introduced to the design and analysis of concepts for heating, cooling and ventilation of buildings. First, students are introduced to national and international building codes and standards. The lecture will give an overview of energy consumption in buildings and building-related CO_2 emissions. Students will research the state-of-the art of buildings and their energy consumption, building codes and requirements on building design in their home country. Results are presented and discussed in class by a short presentation.

Second, fundamental heat transfer processes in buildings are described and quantified including conduction, convection, and radiation. The sensible and latent loads as well as the energy demand for heating, ventilating, and air-conditioning in buildings is calculated. The study includes the physical interaction of climate and buildings and the thermal comfort as well as indoor air quality requirements.

Third, different components and concepts for an energy efficient heating and cooling of buildings are introduced. In particular, focus is given to novel and sustainable concepts using environmental heat sources and sinks as well as renewable energy.

Students will carry out an individual case study using the simulation software Therakles. A typical non-residential building will be modelled and calculated considering the particular location of the building.

Learning goals and qualifications Students will learn to use building automation to optimize building operation, to analyse structural plans of digital building control and to parameterize control cycles of systems for building services. Students are able to evaluate energy saving potentials in optimizations of HVAC systems for daily operation. Students know the existing building control technologies and their applications.
Recommended reading Everything provided in lecture and lab
Course prerequisites Basic knowledge in control techniques and thermodynamics.

<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.
97003</td><td colspan="2">Module name
Energy Informatics</td><td>Semester/return
3rd Sem. / annual</td></tr>
<tr><td>Workload/presence
5 ECTS (150 h/60 h)</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, Exercises, Seminar</td><td>Examination form
Assignments and Written Examination</td><td>Start date
29.01.2018</td><td>Location
Uni Freiburg</td></tr>
<tr><td colspan="4">Module coordinator:
Prof. Dr. Peter Thiemann (Thiemann@informatik.uni-freiburg.de)</td></tr>
<tr><td colspan="4">Additional teaching staff
Prof. Dr. Georg Lausen (lausen@informatik.uni-freiburg.de), Prof. Dr. Christian Schindelhauer (schindel@informatik.uni-freiburg.de), NN</td></tr>
<tr><td colspan="4">Syllabus
1. Networks
1.1. Structure and Technologies of Computer Networks
1.2. The Internet
1.3. Network Algorithms
1.4. Security
1.5. Computer Networks for Smart Grids
2. System design
2.1. Data Modeling
2.2. Relational Databases and SQL
2.3. Data Interchange and Data Integration
3. Data Analysis
3.1. Python Basics
3.2. Applied UML
3.3. Information Sources and Data Conditioning
3.4. Forming and Testing Hypotheses
3.5. Visualization</td></tr>
<tr><td colspan="4">Learning goals and qualifications
Students will learn to use basic techniques for modelling and design of distributed systems in the application domain of energy systems. Students will be able to apply these techniques on basic examples. Students will be familiar with the underlying principles of tools for modelling and will know how to use them.</td></tr>
<tr><td colspan="4">Recommended reading
Everything provided in lecture</td></tr>
<tr><td colspan="4">Course prerequisites</td></tr>
</table>

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses ---			**Instruction Language** English
Module No. **97010**	**Module name** **Photovoltaics 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)** Photovoltaics 1	**No. of participants** Max. 25
Teaching form Lectures, Exercises, Seminar, lab experiments	**Examination form** Written exam	**Start date** 06.11.2017	**Location** University of Freiburg Fraunhofer ISE
Module coordinator: Prof. Dr. Christof Wittwer			
Additional teaching staff: Dr. Ralf Preu (ralf.preu@ise.fraunhofer.de)			

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
- Module technology
- Cost of ownership
- Characterization of cells / material
- Loss mechanisms and improvements
- High efficiency cell concept

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

Basic knowledge of semiconductor physics, "Natural Resources and Conversion Technologies - Photovoltaics"

<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.
97011</td><td colspan="2">Module name
Low Temperature Solar Thermal Energy</td><td>Semester/return
3^{rd} 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)
High Temperature Solar Thermal Energy</td><td>No. of participants
Max. 25</td></tr>
<tr><td>Teaching form
Lectures, Exercises, Excursion, Seminar, lab experiments (depending on students numbers)</td><td>Examination form
Written Exam</td><td>Start date
27.11.2017</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. Peter Schossig, Dr. Andreas Georg</td></tr>
<tr><td colspan="4">Syllabus

In this module the students will learn about low temperature solar thermal energy applications and combinations with energy efficiency measures in buildings. The module focuses on the use of solar in typical heating dominated climates like Central and Northern Europe:
- Market overview
- Solar ressources and technical availability on different part of the building envelope
- Demand profiles for domestic hot water, solar assisted heating, preheating of air
-
- Passive solar concepts and components (windows, transparent insulation, basics of building physics of solar-active buildings)
- Design Basics of flat-plate and vacuum-tube collectors
- Materials and coatings for glazings, absorbers (antireflex, low-emissivity, selectivity)
- Special collector developments e.g. air-collectors, hybrid collectors. PVT Collectors, WISCs, aesthetic concepts for solar thermal building integration BIST
- Performance parameterisation and technical characterisation e.g. efficiency determination, IAM, function test, accelerated aging, quality assurance

- System design concepts for small and large solar thermal systems (performance and economics (design of fields, stagnation, flow-regimes, pressure drop, flow distribution)
- Concepts for Solar thermal driven Cooling
– Thermal storage concepts (sensible short term and seasonal storage) ,)
- Control for active solar systems (e.g. sectoral coupling of heat and electricity, smart controller)</td></tr>
<tr><td colspan="4">Learning goals and qualifications

In this course, students will learn about the use of active and passive solar thermal systems, components used and specifications with respect to the application for heating water, air in buildings and district networks. 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 active and passive solar systems, 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</td></tr>
</table>

solar gains of different systems. They can understand the role of low temperature solar thermal energy conversion in the energy system.
Recommended reading Duffie-Beckman: Solar Engineering of Thermal Processes Volker Quaschning, Understanding Renewable Energy, Earthscan, 2005 Siegel, Howell, *Thermal Radiation Heat Transfer*, 4th ed., Taylor and Francis, New York, 2001. Peuser FA, Remmers K, Schnauss M. Solar thermal systems. Beuth; 2010
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)

<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.
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 / Written exam</td><td>Start date
08.01.2018</td><td>Location
University of Freiburg
Fraunhofer ISE</td></tr>
<tr><td colspan="4">Module coordinator: Prof. Dr. Christof Wittwer</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>

Course			
M.Sc. Renewable Energy Engineering and Management			
Availability to other courses ---			**Instruction Language** English
Module No. **97013**	**Module name** **High Temperature Solar Thermal Energy**		**Semester/return** 3rd Sem. / annual
Workload/presence 5 ECTS (150 h/60 h)	**Prerequisite module(s)** Low Temperature Solar Thermal Energy	**Follow-up module(s)**	**No. of participants** Max. 25
Teaching form Lectures, Exercises, Seminar, lab experiments	**Examination form** Written exam	**Start date** 29.01.2018	**Location** University of Freiburg Fraunhofer ISE

Module coordinator: Prof. Dr. Werner Platzer

Additional teaching staff: Dr. Peter Schossig, Dr. Andreas Georg, Dr. Thomas Fluri (t.b.d.)

Syllabus

In this module the students will learn about high-temperature solar thermal systems with respect to:
- Solar availability and demand profiles for solar thermal power, process heat and cooling
- Concentration of solar radiation
- Solar thermal conversion for temperatures above 100°C using non-concentrating and concentrating collectors
- Concentrating collector technologies (collector concepts, design, materials, manufacturing and assembly)
- Hydraulics and design of collector fields
- Heat-transfer fluids (steam/water, oil, molten salt, etc.)
- High-temperature thermal energy storage (TES) and its role in systems
- Integration of solar thermal heat into industrial processes
- Concentrated solar thermal power (CSP): Solar field concepts, system aspects
- Heat engines and thermodynamic cycles (Rankine, Organic Rankine etc.) in CSP
- Plant control and operation
- Combining of CSP with process steam generation, heating, cooling and desalination
- Project planning, financing and implementation for CSP and solar process heat
- Markets and prospects

Learning goals and qualifications

In this course, students will learn about high-temperature solar thermal systems, components used and specifications with respect to the application for process heat, cooling, climatization and electricity generation. Principles and different concentrating collector types shall be understood and the basic design features known. The conversion of solar radiation to high temperature heat with limitations and aspects will be taught. System analysis with respect to storage concepts, integration of auxiliary sources and flow control will be intensified. Students will learn how to design active solar systems for production of steam, hot fluids and electricity as end product. They will perform simulations and assess the performance and economics of projects. Especially the aspects of steam generation and molten salt technology will be detailed. The students will learn about the interrelations between system components, will get to know different system concepts and will calculate the solar gains of different systems with various methods.

Recommended reading

Duffie-Beckman: Solar Engineering of Thermal Processes.
Lovegrove, K., Stein, W. (Eds.): Concentrating solar Power Technology, Woodhead, 2012
Vogel W, Kalb H. Large-scale solar thermal power: Technologies, costs and development. Wiley-VCH Verlag & Co. KGaA; 2010.
Kreith F, Goswami DY. Handbook of energy efficiency and renewable energy. CRC Press; 2007.
Dinçer İ, Rosen M. Thermal energy storage systems and applications. New York: Wiley; 2002.

Course prerequisites

Content of the module “Natural Resources and Conversion Technologies”

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

It is recommended to participate in the module “Low Temperature Solar Thermal Energy”

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses ---			**Instruction Language** English
Module No. **97021**	**Module name** **Management II**		**Semester/return** 3rd Sem. / annual
Workload/presence 5 ECTS-P (150h/60 h)	**Prerequisite module(s)** Management I	**Follow-up module(s)** ---	**No. of participants** max. 25
Teaching form Lectures, Guest lectures, Case study	**Examination form** Seminar presentation, report/ manual or similar	**Start date** 06.11.2017	**Location** t.b.a.
Module coordinator: Dr. Roderich von Detten (r.v.detten@ife.uni-freiburg.de)			
Teaching staff:			

Syllabus

Whereas the module management I has focused on management from general perspective and deepened knowledge on financial management, strategic management as well as other business management fields (in a business simulation game and in seminar format), management Ii will deepen the acquired knowledge in its application on the renewable energy management examples. During the three weeks, the students will work on selected "real life management case studies" for RE-projects (each to be done by smaller student groups of 4-5 people). As a result, the students will have to provide an extended report/ manual or similar, which will be graded.

The course will be interspersed with an introduction into project management and guest lectures from management experts in RE-organizations/ -projects from different fields.

Learning goals and qualifications

- application of business management instruments
- strategic thinking: application of strategic management concepts
- project management skills and experiences
- insight into different RE management fields, challenges and organizations
- in-depths work on a real life case study, connected with special knowledge there
- 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.

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses **---**			**Instruction Language** English
Module No. **97022**	**Module name** **Landscape, Nature Protection, Landuse conflicts**		**Semester/return** 3rd Sem. / annual
Workload/presence 5 ECTS-P (150/60h)	**Prerequisite module(s)**	**Follow-up module(s)**	**No. of participants** Max. 25
Teaching form Project work	**Examination form** Project report, presentation, group work and excursion	**Start date** 27.11.2017	**Location** t.b.a.
Module coordinator: Prof. Dr. Barbara Koch			
Additional teaching staff: Mirko Mälicke, Joao Paulo Pereira			

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.

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.

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

Course prerequisites:

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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. **97020**	**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. 45
Teaching form Lectures, exercises, group work	**Examination form** Written exam (33%), Term paper + group work (67%)	**Start date** 08.01.2018	**Location** Tba.
Module coordinator: Stefan Pauliuk, PhD (stefan.pauliuk@indecol.uni-freiburg.de)			
Additional teaching staff Prof. Dr. Rainer Grießhammer			

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 short exam (1 hour), 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.

<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.
97023</td><td colspan="2">Module name
Elective II - Bioenergy</td><td>Semester/return
3rd Sem. / annual</td></tr>
<tr><td>Workload/presence
5 ECTS-P (150 / 60h)</td><td>Prerequisite module(s)
Natural Resources and Conversion Technologies</td><td>Follow-up module(s)
none</td><td>No. of participants
Max. 25</td></tr>
<tr><td>Teaching form
Lectures, excursions</td><td>Examination form
Oral Presentation and Group Report, Written Examination</td><td>Start date
29.01.2018</td><td>Location
t.b.a.</td></tr>
<tr><td colspan="4">Module coordinator: Dr. Christian Suchomel</td></tr>
<tr><td colspan="4">Additional teaching staff: Dr. Sebastian Paczkowski</td></tr>
</table>

Syllabus

The module focuses on the conversion of non-wood (agriculture and waste) biomass as well as on their availability and suitability for their respective conversion technologies.

In a first step the availability, transport and storage of biomass will be discussed. Therefore the cultivation and production technologies of energy crops (e.g. corn, miscanthus) in agriculture systems will be presented and discussed. Following this, the supply logistic chains, including harvesting and transportation will be presented on selected examples. Furthermore alternative organic resources (e.g. organic waste) will be in the focus of the lecture. In this context, concepts of an integrated organic waste management will be presented.

In a second step, conversion technologies, which are mainly suitable for agricultural biomass and waste, will be presented and discussed in detail, focussing on the chemical engineering aspects. The following conversion technologies are considered:

- bio-gas from anaerobe digestion
- bio-oil from pressing and extraction / bio-diesel from transesterfication
- bio-ethanol from fermentation

Excursions within the module will provide practical background information and give examples especially for biogas technology.

A project work, reflecting and integrating the lecture content, will be part of the module. The students should select a place/technology of their choice and develop a preliminary assessment of the feasibility of their idea, utilizing the skills learned in the module.

Learning goals and qualifications

The students understand the basic concepts of production and conversion technologies for non-woody biomass.

In particular, students will learn about biomass on agricultural land systems. Techniques of cultivation, harvesting and logistics will be explained, so the students will be able to design a concept for sustainable use of non-wood biomass.

The students will be able to make a preliminary analyses of profitability, efficiency and sustainability.

The students will practice how to summarize essential information and to present them in written and oral form.

Recommended reading: Specific literature will be recommended during the module. For general reading see e.g.: Biogas Handbook, Download: http://lemvigbiogas.com/ Jathropa Handbook: http://www.jatropha.pro/PDF%20bestanden/FACT_Foundation_Jatropha_Handbook_2010.pdf
Course prerequisites The part "Bioenergy" of 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. **93340**	**Module name** **Project**		**Semester/return** 3rd Sem. / each semester
Workload/presence 5 ECTS-P (150h/2h)	**Prerequisite module(s)** Research Skills, Elective I	**Follow-up module(s)** ---	**No. of participants** Max. 75
Teaching form Lecture, self study,	**Examination form** Written report	**Start date** 19.02.2018	**Location** t.b.a.
Module coordinator: Stefan Pauliuk, PhD (stefan.pauliuk@indecol.uni-freiburg.de)			
Additional teaching staff: All lecturers of REM study programme			

Syllabus

- During REM study programme – especially the modules “internship”, “Elective I” and “Elective II” research related projects are being identified by the students and the associate professor.
- The goal of the module is that each student identifies the research topic of own interest. Using the knowledge acquired in the module “Research Skills”, each student should develop a research proposal that meets the standards for a master thesis proposal in REM.
- The proposal should describe at least the problem statement, research questions, literature review (state of the art), methodology, expected results, time and budget plan and a proposed table of content of the thesis.

Milestones:

- At the beginning: selection/identification of research topic
- Searching the supervisor (professor)
- At the end of the module: presentation of the proposal and project report

Learning goals and qualifications

Students will learn

- how to structure a research or development project, such that it makes sense and is doable
- write a project proposal that is informative to non-project-related readers
- refine and revise their ideas through an iterative communication process with their supervisor

Recommended reading

Information about recommended reading will be provided by supervising professor individually.

Course prerequisites

Modules Research Skills and Elective I.

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses ---			**Instruction Language** English
Module No. **93952**	**Module name** **Generation and Distribution of Energy**		**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, excursions, seminar, lab experiments	**Examination form** Exam	**Start date** 09.04.2018	**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 our today's electricity system actually works. In this module, today's energy systems are discussed from the energy production via the distribution of the electricity to the socket of the end user. This includes the technological view of energy production by classical power plants; transformation of energy and the different voltage levels, as well as the stabilisation of and the distribution by the electricity grid.

The distribution of renewable energy sources is discussed and the geographic information systems introduced. Geographical presentation and analyses of electricity networks in Geographical Information Systems (GIS) helps to understand current distribution grids and optimize planning for future demands. Basics in data formats, data bases, creation of data and modelling will be taught.

Learning goals and qualifications

The students acquired 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 by the electricity grid and know what can be done to solve challenges in the system stability and the security of supply.

The students get hands on information on managing, analyses and presentation of data in electricity networks.

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="3">Course
M.Sc. Renewable Energy Engineering and Management</td><td>Instruction Language
English</td></tr>
<tr><td colspan="3">Availability to other courses
---</td><td></td></tr>
<tr><td>Module No.
93220</td><td colspan="2">Module name
Management I</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
Seminar presentation, written exam</td><td>Start date
30.04.2018</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 economics
   - 1.1 Fundamental terms of economic activity
     (Allocation, distribution, division of labour, exchange, micro- and macroeconomic flow of goods and money).
   - 1.2 Typology of economic units
     (Households - firms - organisations in the so-called tertiary sector)
   - 1.3 Typology of economic systems
     - overview
     - focus: social and ecological committed market economy
     - normative underpinnings: efficiency, ecological sustainability, justice
     - coordination mechanisms: state - market – civil society
   - 1.4 About the interplay of the political and the economic system
2. Basics of management
   - 2.1 Overview: What is management about?
   - 2.2 Economical dimension – added value in firms (Business Simulation “Factory”)
   - 2.3 Social dimension – the firm is an organisation
   - 2.4 Ecological consequences of commercial action
   - 2.5 Goals and decisions in the focus of entrepreneurial action
   - 2.6 Management cycle – planning, organisation, human resources, accounting, controlling
3. Project management
4. Strategical Management

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.

Course

M.Sc. Renewable Energy Engineering and Management

Availability to other courses			**Instruction Language**
---			English
Module No.	**Module name**		**Semester/return**
93953	**Society & Economy**		2^{nd} Sem. / annual
Workload/presence	**Prerequisite module(s)**	**Follow-up module(s)**	**No. of participants**
5 ECTS-P (150/60h)	Scientific Framework for REM		max. 75
Teaching form	**Examination form**	**Start date**	**Location**
Lectures, Exercises, Excursions, Seminar	Excursion Reports, Seminar presentation, Written Exam	28.05.2018	t.b.a

Module coordinator: Prof. Dr. Stefan Baumgärtner

Additional teaching staff:

Syllabus

- Energy markets
  - Energy demand analysis
  - Market structure: competitive vs. monopoly vs. oligopoly
  - Energy pricing
- Risk analysis and management
  - Decision-making under uncertainty; microeconomics of insurance
  - Macroeconomics of insurance
  - Portfolio investments
- Market failure and regulation
  - Externalities and regulation
  - Regulation of heterogeneous pollution sources

  Public goods and open access resources

Learning goals and qualifications

Students should have knowledge and understanding on:

- energy markets and the role of markets in efficient allocation of energy
- how to adapt standard microeconomic theory to incorporate economic risk associated with renewable energies
- what happens when markets don't work as expected – market failure in the allocation of energy

Recommended reading

Reading material will be provided on the learning platform ILIAS

Course prerequisites

Module "Scientific framework" – in particular, the economics part

<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 (a)</td><td colspan="2">Module name
Research Skills – Geothermal Energy</td><td>Semester/return
2nd Sem. / annual</td></tr>
<tr><td>Workload/presence
5 ECTS-P (150/60h)</td><td>Prerequisite module(s)
Natural Resources and Conversion Technologies</td><td>Follow-up module(s)
---</td><td>No. of participants
Max. 30</td></tr>
<tr><td>Teaching form
Lecture with discussion + supervised exercises + excursions</td><td>Examination form
Marked assignments and project work</td><td>Start date
18.06.2018</td><td>Location
t.b.a.</td></tr>
<tr><td colspan="4">Module coordinators: Stefan Pauliuk, PhD (stefan.pauliuk@indecol.uni-freiburg.de)</td></tr>
<tr><td colspan="4">Additional teaching staff: Prof. Dr. Stefan Hergarten, Dr. Matthias Geyer, Dr. Johannes Miocic</td></tr>
</table>

Syllabus

The module covers the following topics:

- Basics of heat transport (conduction, advection)
- Global and local geothermal potential
- Shallow geothermal systems (downhole heat exchangers, heat collectors)
- Seasonal heat storage
- Closed deep geothermal systems and their potential for direct heating
- Hydrothermal systems
- Petrothermal systems
- Environmental aspects

The theory is presented and discussed in the lecture, while the obtained knowledge is deepened in the supervised exercises. These exercises prepare the students for considering project studies on the different types of geothermal systems that will contribute the largest part to the students' workload. In addition, two excursions (Staufen and a geothermal power plant) are planned.

Learning goals and qualifications

The students learn how to

- assess the geothermal potential at a given location and to
- design geothermal systems for different purposes (electricity, heating) with focus on feasibility, economic efficiency and sustainability.

Recommended reading

C. Clauser: Geothermal Energy, in: K. Heinloth (Ed), Landolt-Börnstein, Group VIII, Vol. 3C: Energy Technologies -- Renewable Energy, 493--595 (Springer)

I. Stober & K. Bucher: Geothermal Energy (Springer)

Course prerequisites

Basic knowledge in calculus

<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 (b)</td><td colspan="2">Module name
Research Skills – Hydropower</td><td>Semester/return
2^{nd} Sem. / annual</td></tr>
<tr><td>Workload/presence
5 ECTS-P (150/60h)</td><td>Prerequisite module(s)
“Natural Resources and Conversion Technologies”</td><td>Follow-up module(s)
---</td><td>No. of participants
Max. 30</td></tr>
<tr><td>Teaching form</td><td>Examination form
Exercises and project work (short essay)</td><td>Start date
18.06.2018</td><td>Location
t.b.a.</td></tr>
<tr><td colspan="4">Module coordinators: Stefan Pauliuk, PhD (stefan.pauliuk@indecol.uni-freiburg.de)</td></tr>
<tr><td colspan="4">Additional teaching staff: Dr. Stefan Pohl</td></tr>
</table>

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

<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.
93931</td><td colspan="2">Module name
Elective Bioenergy I</td><td>Semester/return
2nd Sem. / annual</td></tr>
<tr><td>Workload/presence
5 ECTS-P (150 / 60h)</td><td>Prerequisite module(s)
Natural Resources and Conversion Technologies</td><td>Follow-up module(s)
Elective II</td><td>No. of participants
Max. 35</td></tr>
<tr><td>Teaching form
Lectures, excursions</td><td>Examination form
Written Exam</td><td>Start date
09.07.2018</td><td>Location
T.b.a.</td></tr>
</table>

Module coordinator: Dr. Christian Suchomel

Additional teaching staff: Dr. Sebastian Paczkowski

Syllabus

The module will introduce the most relevant energy conversion technologies related to woody biomass. In addition, aspects of production, harvesting, logistic, and storage of wood will be addressed. A detailed presentation of biomass processing including pellet production is given together with chemical engineering aspects of conversion processes such as:

- torrefaction, pyrolysis
- gasification, BtL
- combustion

Advantages and disadvantages of these processes will be discussed in terms of biomass resources, production technology, product characteristics, and emissions. .

Excursions within the module will complement the theoretical aspects.

A group work that comprises a management and technology concept for a selected place/technology will allow the students to apply their knowledge and prove project's feasibility.

Learning goals and qualifications

The students will learn fundamental concepts of conversion processes for woody biomass and get a basic understanding of related technologies. They will be able to assess different technologies with respect to strengths and weaknesses.

Furthermore, the students will learn to assess the potentials of woody 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.

<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.
93933</td><td colspan="2">Module name
Elective Wind energy</td><td>Semester/return
3rd Sem. / annual</td></tr>
<tr><td>Workload/presence
5 ECTS-P (150h/60h)</td><td>Prerequisite module(s)
Elective I</td><td>Follow-up module(s)
---</td><td>No. of participants
Max. 45</td></tr>
<tr><td>Teaching form
Lectures, Excursion</td><td>Examination form
Written exam</td><td>Start date
09.07.2018</td><td>Location
t.b.a.</td></tr>
<tr><td colspan="4">Module coordinator: Prof. Dr. Mario Ragwitz</td></tr>
<tr><td colspan="4">Additional teaching staff: Dr. Marian Klobasa, Daniel Kowalski</td></tr>
</table>

Syllabus

The Wind Energy module will give the students a brief but thorough introduction to the science and technology of wind turbines and utilization of wind energy for power generation.
The module will be structured into the following components:

- Introduction and motivation: Development of wind energy in Europe and globally
- Consolidating basic knowledge of wind energy technology already provided in module "Technology II"
- Potential assessment and geo-modeling of sites including environmental aspects
- Economics of wind power and wind energy project development
- Integration of wind power into the electricity system
- Policy design for the future development of wind energy

The first component will present the past and present status of wind energy and its contribution to the overall energy mix, introduce recent economic and technical developments and challenges of wind energy, main drivers and barriers as well as future scenarios of wind energy development.

The second component will review the fundamentals of wind and wind harvesting incl. the stochastic nature of the wind and the statistic parameters, the aerodynamics of wind turbines and the technological characterisation of wind turbines / system components. This will include statistical tools used to describe the wind (Weibull, etc.), the physics of a wind turbine including the Betz limit, the aerodynamics of turbine blades and the mechanics of wind turbines and turbine types (power curve, capacity factor, stall vs. pitch wind turbines, direct drive vs. geared turbine).

The third component will start with an introduction to geographical information systems (GIS) to allow the presentation of techniques of geo-modelling of wind sites and GIS-based assessment of wind potentials. This will include the consideration of environmental constraints of wind park planning.

The fourth component will cover the practical realisation and economics of wind power projects. From a project developers perspective the following aspects will be presented:

- Acquisition of a project, technical project management, wind park planning
- Due Diligence of the entire project
- Financial Issues/Business Models

The fifth component concentrates on the integration of wind energy in the energy system based on the challenges of fluctuating electricity generation It contains key approaches to facilitate system and grid integration of wind energy incl. network expansion requirements as well as strategies for increasing the flexibility of the power system.

The final component will present best practices of policy design for wind energy in the context of different energy economic framework conditions incl. approached for improved market introduction of wind energy.

If possible the Wind Energy Module will also include a field trip to a local wind turbine in Baden-Württemberg.

The lessons learned from the module components will be utilized by the students in the final project.

Learning goals and qualifications

- Knowledge on main drivers and barriers for wind energy development in the EU and globally
- Understanding of the stochastic nature of the wind and the statistic parameters used to summarize the wind.
- Introduction to the physics and mechanics of wind power and the physical limits.
- Basic understanding of the various turbine typologies and economic reasoning behind the types.
- Understanding the methodology of GIS based assessment of wind energy potentials
- Fundamental understanding of the issues involved with wind park planning, including the necessity to understand local conditions, including social/political/environmental issues.
- Knowledge on the practical realization of wind projects from a technical and economic perspective
- Basic understanding of approaches to system and market integration of wind energy
- Insights into the design of effective and economically efficient policies for wind energy
- Additional general skills: rhetoric, discussion and presentation skills, capacity for team work

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

Wind Energy – the Facts: Technology, Economics, grid integration, industry and markets and environmental issues of wind power **(http://www.wind-energy-the-facts.org/)**

Wind energy explained* : theory, design and application / J. F. Manwell and J. G. McGowan ; A. L. Rogers. - 2. ed.. - Chichester : Wiley, 2009

Wind turbines* : fundamentals, technologies, application, economics; Erich Hau. - 2. ed.. - Berlin ; Heidelberg [u.a.] : Springer, 2006

Wind Energy Handbook – Burton et al.

Wind Power Plants: Fundamentals, Design, Construction and Operation– Gasch, Twele

http://windpower.org/en/

Course prerequisites

None.

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses ---			**Instruction Language** English
Module No. 6900	**Module name** **Internship (Praktikum)**		**Semester/return** 2nd - 3rd Sem. / annual
Workload/presence 10 ECTS-P (300 h)	**Prerequisite module(s)** ---	**Follow-up module(s)** ---	**No. of participants** max. 75
Teaching form Practical work	**Examination form** Written report	**Start date** 30.07.2018	**Location** t.b.a.

Module coordinators: Stefan Pauliuk, PhD (stefan.pauliuk@indecol.uni-freiburg.de)

Additional teaching staff

Academic experts of the respective internship institution

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

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.

Recommended reading

None.

Course prerequisites

None.