Module handbook

REM M.Sc. Renewable Energy Engineering and Management

Academic year 2019/2020

State of 04.10.2019

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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

	Winter term 2019/20 First Semester																										
	October				November					December				January					February				March				
CW				43	44	45	46	47	48	49	50	51	52	01	02	03	04	05	06	07	08	09	10	11	12	13	CW
	11.10.			21.10 - 20.12.									- 6.01.		07.01 - 24.01.			27.01. - 14.02.			17.02. - 06.03.						
REM (1st Sem.)	Introductory day			Module Energy & Sustainable Development									Christmas Break		Module Natural Resources and Conversion Technologies						Module Climate & Energy Policy						REM (1st Sem.)
				Pauliuk																							
				Module Scientific Framework for REM																							
				Pauliuk											Pauliuk						Ragwitz						

	April			May				June			July					August				
CW	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	...

CW	20.04. - 08.05.	11.05. - 29.05.	01.- 07.6	08.06. - 26.06.	29.06. - 17.07.	20.07. - 07.08.		CW
REM (2nd Sem.)	Module **Energy Systems Operations**	Module **Introduction to Business Manage-ment**	**Pentecoast Break**	Module **Research Skills and Ethics for Sustainable Development**	Module **Elective Hydropower,** **Elective Global Sustainability Transformations in Local Contexts**	Module **Elective Bioenergy I,** **Elective Wind energy**	Module **Internship**	REM (2nd Sem.)
	Weidlich	**von Detten**		**Pauliuk**	**Weiler** **Zengerling**	**Fillbrandt** **Schindler**	**Pauliuk**	

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

Winter term 2019/20 Third Semester

	October	November	December	January	February	March		
CW	43 44 45	46 47 48	49 50 51	52 01	02 03 04	05 06 07	08 09 10	11 12
	21.10 – 08.11.	11.11. - 29.11.	02.12. – 20.12.	- 6.01.	07.01–24.01.	27.01. – 14.02.	17.02. – 06.03.	
REM (3rd Sem.)	Module	Modules Elective Tracks	Modules Elective Tracks	Christmas Break	Modules Elective Tracks	Modules Elective Tracks	Module **Project**	
	Operations Research for Energy Systems **Complex Networks** **Energy Informatics** **Smart Grids** **Modelling and System Identification** **Energy Storage,Energy in Buildings, Python**				**Weidlich** **Schäfer** **Thiemann** **Wittwer** **Diehl** **Vetter, Henning, Weidlich**			
	Internship	**Photovoltaics 1**	**Low Temperature Solar Thermal Energy**		**Photovoltaics 2**	**High Temperature Solar Thermal Energy**		
		Management 2	**Landscape, Nature Protection, Landuse Conflicts**		**Life Cycle Management** **Environmental and Energy Transition Law**	**Bioenergy 2** **Research Methods in Industrial Ecology**		
	Pauliuk	**Henning** **von Detten**	**Platzer** **Koch**		**Henning** **Pauliuk,** **Zengerling**	**Platzer** **Pauliuk** **Pauliuk**	**Pauliuk**	

3. Module descriptions

3.1. Winter term 2019/2020 – first semester

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

3.2. Winter term 2019/2020 – third semester

- **Internship**
- **Elective Track "Energy Systems Technology"**
  - ❖ **Operations Research for Energy Systems**
  - ❖ **Complex Networks**
  - ❖ **Energy Informatics**
  - ❖ **Smart Grids**
  - ❖ **Modelling and System Identification**
  - ❖ **Energy Storage**
  - ❖ **Energy in Buildings: components and systems for energy supply**
  - ❖ **Python for Energy System and Sustainability Analysis**
- **Elective Track "Renewable Energy Planning and Management"**
  - ❖ **Management 2**
  - ❖ **Landscape, Nature Protection, Landuse conflicts**
  - ❖ **Life Cycle Management**
  - ❖ **Environmental and Energy Transition Law**
  - ❖ **Bioenergy 2**
  - ❖ **Research Methods in Industrial Ecology**

- **Elective Track “Energy Conversion”**
  - ❖ **Photovoltaics 1**
  - ❖ **Low Temperature Solar Thermal Energy**
  - ❖ **Photovoltaics 2**
  - ❖ **High Temperature Solar Thermal Energy**

3.3. Summer term 2020 – second semester

- **Energy Systems Operations**
- **Introduction to Business Management**
- **Society and Economy**
- **Research Skills and Ethics of Sustainable Development**
- **Elective Hydropower**
- **Elective Global Sustainability Transformations in Local Contexts**
- **Elective Bioenergy I**
- **Elective Wind Energy**
- **Internship**

Course

M.Sc. Renewable Energy Management

Availability to other courses			**Instruction Language**
----			English
Module No.	**Module name**		**Semester/return**
93110	**Energy and sustainable development**		1st Sem. / annual
Workload/presence	**Prerequisite module(s)**	**Follow-up module(s)**	**No. of participants**
5 ECTS-P (150h/60h)	---	---	Max. 75
Teaching form	**Examination form**	**Start date**	**Location**
Lectures, exercises, group work	Term paper (50%), written exam (50%)	21.10.2019	Tba.

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

Additional teaching staff

Prof. Dr. Ernst Ulrich von Weizsäcker

Syllabus

The module is divided into three parts.

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

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

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

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

Learning goals and qualifications

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

Recommended reading

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

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

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

Course prerequisites

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

<table>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses
---</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
93950</td><td colspan="2">Module name
Scientific Framework for REM</td><td>Semester/return
1st Sem. / annual</td></tr>
<tr><td>Workload/presence
10 ECTS (300h/100h)</td><td>Prerequisite module(s)
---</td><td>Follow-up module(s)
---</td><td>No. of participants
max. 75</td></tr>
<tr><td>Teaching form
Lectures, tutorials</td><td>Examination form
Written exam (pass or fail)</td><td>Start date
21.10.2019</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: Christoph Bohnert, Dr. Roderich von Detten, Kathrin Drozella, Dr. Gunnar Gidion, Dr. Oswald Prucker, Dr. Michael Henze, Prof. Cathrin Zengerling</td></tr>
<tr><td colspan="4">Syllabus
This module is designed to harmonize the heterogeneous background knowledge due to the interdisciplinary and internationality nature of the M.Sc. REM course by providing fundamental knowledge about diverse subjects relevant for this course. At the beginning, the current knowledge in physics, chemistry, biology, engineering, politics, economics, business, and law will be tested and recommendations will be given to the student, which lectures with a total workload of 10 ECTS they should take to fill their knowledge gaps
1. Introduction in Physics, Chemistry, Biology and Engineering
In this module, the basics of mechanics, thermodynamics, electro statics and dynamics, as well as optics are discussed in a physics class. An overview over the chemistry (e.g. assembly of elements, chemical bindings, chemical reactions, organic molecules, polymers) and biology (e.g. photosynthesis, cells in a perspective of biomass) is given. An engineering class provides the students with the fundamental knowledge on electricity (e.g. basics of electronics, electric components, Kirchhoff's laws, diodes, three-phase current)
2.Introduction into Politics, Economics, Business and Law
The economics part of the course presents an overview of basic concepts and methods of microeconomics. Main topics include fundamental principles of economics, consumer theory, producer theory, and market equilibrium and efficiency.
Basics of business economics: Financial Management, Accounting, Balance sheet, performance indicators (liquidity, profitability, financial health etc.), Strategic Aspects of Management; Decision Making in organizations (teaching form: cardboard business game)
The law module introduces into fundamentals of law and state theory from an international, multi-level governance and comparative perspective. It presents basics of the legal framework relevant for renewable energies and makes students familiar with key legal primary sources in this context.</td></tr>
<tr><td colspan="4">Learning goals and qualifications
1. Introduction in Physics, Chemistry, Biology, and Engineering
The students acquire basic knowledge in physics and engineering to provide the required prerequisites for advanced technology classes. The students understand the concepts of thermodynamics, mechanics, electro statics and dynamics, and optics as well as the electric engineering, which consists of electrical components, electrical circuits and conduction. The students learn fundamental concepts of chemistry and biology providing a basis for understanding biomass and conversion into bioenergy. This includes the classifications and properties of basic elements of the periodic table and survey the different bonding mechanisms and resulting chemical species, the fundamentals of chemical reactions including stoichiometry with a specific emphasis on reactions relevant to biomass such as acid / base reactions.</td></tr>
</table>

2.Introduction into Politics, Economics, Business and Law Students acquire adequate understanding of microeconomic theory and they are able to apply this to practical contexts. The economics part builds on the basic concepts in consumer and producer theory. They understand the principles of the legal framework of land use as well as the role of organizations as bottlenecks for the implementation of sustainability strategies. Students understand the rational of social and economic sciences (methodology, methods). They are able to adopt theoretical concepts to practical questions and use them as a tool to understand the formulation and implementation of energy policy. Students gain an overview of fundamentals of law and state theory, energy and planning law and learn how this legal framework shapes the renewable energy market.
Recommended reading Tipler, Mosca: Physics for Scientists and Engineers; Freeman, 6th edition, 2007 (Part I, II, III, IV, V) Boylestad, Nashelsky, Electronic Devices and Circuit Theory, Prentice Hall, 7th edition Orrrest M. Mims, Getting Started in Electronics, 12th edition (1994) – *soft copy for the students will be provided*. Economy & Management: Selected chapters from : Cole, G. a. 2003. Management. Theory and Practice. 6th edition. Cengage Learning (UK) & Parkin, M., Powell, M. and Matthews, K. 2003 Economics, 5th Edition, Harlow: Addison-Wesley; during the module materials will be made available via the learning platform ILIAS
Course prerequisites **-**

<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
07.01.2020</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
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 water cycle and hydrological processes as well as the large number of different technologies and applications for producing hydropower and hydroelectricity. The state of hydropower worldwide and in certain countries will be addressed and calculations for hydropower and hydroelectricity output will be done. Further topics are: hydropower and environment, hydropower and climate change, river ecology scientific discussion on dams), aspects of hydropower economics, sustainable management of hydropower and case studies around the world.

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

4. 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
17.02.2020</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

<table>
<tr><td colspan="3">Course
M.Sc. Renewable Energy Engineering and Management</td><td></td></tr>
<tr><td colspan="3">Availability to other courses
----</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
97007</td><td colspan="2">Module name
Operations Research for Energy Systems</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, exercises</td><td>Examination form
Written exam and homework assignment</td><td>Start date
21.10.2019</td><td>Location
t.b.a.</td></tr>
</table>

Module coordinator: Prof. Dr. Anke Weidlich

Additional teaching staff:

Syllabus

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

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

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

Learning goals and qualifications

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

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

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

Course prerequisites

None.

Course

M.Sc. Renewable Energy Engineering and Management

Availability to other courses			**Instruction Language**
SSE			English
Module No.	**Module name**		**Semester/return**
97008	**Complex Networks**		3rd Sem. / annual
Workload/presence	**Prerequisite module(s)**	**Follow-up module(s)**	**No. of participants**
6 ECTS (180 h/70 h)		Elective II Energy Efficiency	Max. 20
Teaching form	**Examination form**	**Start date**	**Location**
Lecture with integrated exercises	Written exam	21.10.2019	Uni Freiburg

Module coordinator:

Dr. Mirko Schäfer

Additional teaching staff

Syllabus

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

Learning goals and qualifications

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

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

Recommended reading

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

Course prerequisites

Basic knowledge of matrix and probability theory.

<table>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses
---</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
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
21.10.2019</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. 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** 21.10.2019	**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”

<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.
97009</td><td colspan="2">Module name
Modelling and System Identification</td><td>Semester/return
3rd Sem. / Winter term / elective</td></tr>
<tr><td>Workload/presence
6 ECTS-P (180h: 64h class, 116h self-study) / 3 lectures + 1 exercise</td><td>Prerequisite module(s)
---</td><td>Follow-up module(s)
---</td><td>No. of participants</td></tr>
<tr><td>Teaching form
Lecture and exercises</td><td>Examination form
Written or oral examination</td><td>Start date</td><td>Location
IMTEK; Lehrstuhl Systemtheorie</td></tr>
<tr><td colspan="4">Module coordinators: Prof. Dr. M. Diehl</td></tr>
<tr><td colspan="4">Additional teaching staff:</td></tr>
<tr><td colspan="4">Syllabus
Aim of the module is to enable the students to create and identify models that help to describe and predict the behaviour of dynamic systems. In particular, students shall become able to use input-output measurement data in form of time series to identify unknown system parameters and to assess the validity and accuracy of the obtained models.</td></tr>
<tr><td colspan="4">Learning goals and qualifications
Linear and Nonlinear Least Squares, Maximum Likelihood and Bayesian Estimation, Cramer-Rao-Inequality, Recursive Estimation, Dynamic System Model Classes (Linear and Nonlinear, Continuous and Discrete Time, State Space and Input Output, White Box and Black Box Models), Application of identification methods to several case studies. The lecture course will also review necessary concepts from the three fields Statistics, Optimization, and Systems Theory, where needed.</td></tr>
<tr><td colspan="4">Recommended reading
• Lecture manuscript
• Ljung, L. (1999). System Identification: Theory for the User. Prentice Hall
• Lecture manuscript "System Identification" by J</td></tr>
<tr><td colspan="4">Course prerequisites (recommended)
Knowledge of
• Mathematics I for Engineers and Computer Scientists
• Mathematics II for Engineers
• Differential Equations
• Systems Theory and Feedback Control</td></tr>
</table>

<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.
97005</td><td colspan="2">Module name
Energy Storage</td><td>Semester/return
1st Sem. / Winter term / mandatory</td></tr>
<tr><td>Workload/presence
5 ECTS-P (150h: 56h class, 94h self-study) / 3 lectures + 1 exercise</td><td>Prerequisite module(s)
---</td><td>Follow-up module(s)
---</td><td>No. of participants
5</td></tr>
<tr><td>Teaching form
Lecture and exercises</td><td>Examination form
Written or oral examination</td><td>Start date</td><td>Location
INATECH</td></tr>
<tr><td colspan="4">Module coordinators: M. Vetter</td></tr>
<tr><td colspan="4">Additional teaching staff: D. Schossig, T. Smolinka</td></tr>
<tr><td colspan="4">Syllabus
1. Introduction and motivation energy storage (electric, thermal, PtG): Large-scale integration of renewable energies and the role of energy storage; technical requirements of power grids; overview of energy storage options and applications; key parameter of energy storage systems; technical requirements of storage systems; economic analyses for storage systems
2. Basics of energy storage systems: Mechanical (pumped hydro, CAES, fly wheels); Electric (SuperCaps); Electrochemical (Lead-acid, NiCd, NiMh, Lithium-ion; Sodium-ion; NaS / NaNiCl); thermal storage systems; chemical storage and PtG systems
3. Design of battery systems (focus Lithium-ion): Test and characterization of cells; Battery module and system design (components, construction, cooling); Safety issues; Battery management; Thermal management; System integration (system options, power and communication interface); Peripheral components (inverter, energy management)
4. Design of thermal storage systems
Description of technologies: sensible heat storage, latent heat storage, thermochemical storage. Technical applications: long term storage, short term storage, from cold storage to high temperature storage. Component and system layout, best case examples, limits and future expectations
5. Design of hydrogen storage and PtG systems: different system layouts and main components of hydrogen and PtG storage systems, water electrolysis as core component for PtG systems, advantages and drawbacks for repowering in fuel cells and thermal engines, best case examples of PtG installations, intersectoral extention to further Power-to-X technologies

The lecture will be accompanied by a weekly exercise to deepen the understanding of the lecture's content and to discuss further details.</td></tr>
<tr><td colspan="4">Learning goals and qualifications
• Understanding the necessity of energy storage (short-term, mid-term, seasonal) for stationary applications (electric, thermal and chemical) as well as their technical and economic requirements
• Basic knowledge of different energy storage technologies such as pumped-hydro, SuperCaps, batteries, and thermal storage systems as well as hydrogen and Power-to-Gas (PtG) solutions
• Knowledge in design of battery systems with a focus on lihtium-ion technologies
• Knowledge in design of thermal storage systems
• Knowledge in design of hydrogen storage and PtG systems</td></tr>
</table>

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

<table>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses
---</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
97030</td><td colspan="2">Module name
Energy in Buildings: components and systems for energy supply</td><td>Semester/return
3rd Sem. / Winter term / elective</td></tr>
<tr><td>Workload/presence
3 ECTS-P (90h: preparation + lecture) / 2h lecture*</td><td>Prerequisite module(s)
Energy in Buildings: energy demand and building physics</td><td>Follow-up module(s)
Energy in Buildings: energy demand and building physics</td><td>No. of participants
5</td></tr>
<tr><td>Teaching form
Lecture (min. 80% attendance)</td><td>Examination form
Written or oral</td><td>Start date</td><td>Location
INATECH</td></tr>
<tr><td colspan="4">Module coordinators: Prof. Dr. H.-M. Henning</td></tr>
<tr><td colspan="4">* It is planned to extend the module to 6 ECTS from winter term 2019/20 on</td></tr>
</table>

Syllabus

Covered technologies:
- Burners, condensing boiler technology
- Combined heating and power (CHP) units for buildings
- Heat transformation: principles, compression, absorption, adsorption
- Solar energy utilization: principles, solar thermal collectors, photovoltaics applied in buildings
- Energy storage: thermal storage, electrical storage and their system integration

Beside the technologies overall systems are analysed and specific figures of merit to assess different technical solutions are defined and applied. Basic methods for cost assessment as well as methods to assess building sustainability are presented and discussed.

Exercises are included into the lecture.

Learning goals and qualifications

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

Recommended reading

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

Course prerequisites (recommended)

Energy Storage, Solar Energy

<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.
97006</td><td colspan="2">Module name
Python for Energy System and Sustainability Analysis</td><td>Semester/return
2nd Sem. / Summer term / elective</td></tr>
<tr><td>Workload/presence
6 ECTS-P (180h: 45h class, 60h preparation, 75h project) / 4 computer lab + integrated lectures</td><td>Prerequisite module(s)
---</td><td>Follow-up module(s)
---</td><td>No. of participants
15</td></tr>
<tr><td>Teaching form
Computer lab and lecture</td><td>Examination form
Project and presentation*</td><td>Start date</td><td>Location
INATECH</td></tr>
<tr><td colspan="4">Module coordinators: Prof. Dr. Anke Weidlich</td></tr>
<tr><td colspan="4">Additional teaching staff: Jan-Frederick Unnewehr, Ramiz Qussous</td></tr>
<tr><td colspan="4">*Students choose an own research challenge, decide on a model for addressing the challenge, implement it in Python, execute it with appropriate input data, plot and interpret results, and describe the project in a report. They present their project in the class.</td></tr>
<tr><td colspan="4">Syllabus
• General introduction to Python, integrated development environment
• Fundamentals (data types, expressions, conditional execution, iterations, functions, files, matrix operations)
• Introduction to numerical methods (e. g. numerical differentiation, integration, fixed-point iteration, differential equations)
• Algorithms (flowcharts, pseudocode, complexity and runtime estimation)
• Modelling techniques and application examples from energy systems and sustainability analysis (power flow analysis, merit order models, simulations, system dynamics and others)
• Relevant data sources for the energy sector
• Data evaluation (data import and export, plotting results)

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

Course prerequisites (recommended)
Control and Integration of Grids

<table>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses
---</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
97010</td><td colspan="2">Module name
Photovoltaics 1</td><td>Semester/return
3rd Sem. / annual</td></tr>
<tr><td>Workload/presence
5 ECTS (150 h/60 h)</td><td>Prerequisite module(s)
Natural Resources and Conversion Technologies</td><td>Follow-up module(s)
Photovoltaics 1</td><td>No. of participants
Max. 25</td></tr>
<tr><td>Teaching form
Lectures, Exercises, Seminar, lab experiments</td><td>Examination form
Written exam</td><td>Start date
11.11.2019</td><td>Location
University of Freiburg
Fraunhofer ISE</td></tr>
<tr><td colspan="4">Module coordinator: Prof. Dr. Hans-Martin Henning</td></tr>
<tr><td colspan="4">Additional teaching staff: Dr. Ralf Preu (ralf.preu@ise.fraunhofer.de)</td></tr>
</table>

Syllabus

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

- Basics of semiconductor physics
- Photogeneration and recombination, carrier transport
- pn- Junction and IV-characteristics
- Silicon: Quartz, metallurgical silicon, crystallization, wafer cutting
- Industrial silicon solar cell production
- 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”

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses ---			**Instruction Language** English
Module No. **97011**	**Module name** **Low Temperature Solar Thermal Energy**		**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)** High Temperature Solar Thermal Energy	**No. of participants** Max. 25
Teaching form Lectures, Exercises, Excursion, Seminar, lab experiments (depending on students numbers)	**Examination form** Written Exam	**Start date** 02.12.2019	**Location** University of Freiburg Fraunhofer ISE
Module coordinator: Prof. Dr. Werner Platzer			
Additional teaching staff: Dr. Korbinian Kramer, Dr. Peter Schossig, Dr. Andreas Georg			

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)

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 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
07.01.2019</td><td>Location
University of Freiburg
Fraunhofer ISE</td></tr>
<tr><td colspan="4">Module coordinator: Prof. Dr. Hans-Martin Henning</td></tr>
<tr><td colspan="4">Additional teaching staff: Dr. Ralf Preu (ralf.preu@ise.fraunhofer.de)</td></tr>
<tr><td colspan="4">Syllabus
A seminar about specific topics of PV technology, systems and costs thereof (e.g. review of different approaches for the calculation of levelized cost of PV electricity or Review of PV Technology for industrial high efficiency solar cells). The three week course will be distributed into 3 phases.
1st week: topic collection, group definition (up to 5 groups min. 2 person per group), introduction to the topic by a tutor including distribution of literature and work within the group, study of literature, one additional appointment with tutor at the end of the week to discuss open points and structure of the presentation and report.
2nd week: preparation of final presentation, two-day seminar with presence requested by all, each individual member of a group has to give a sub-presentation.
3rd week: Groups will have to hand in a report on the review (max. 10 pages) at the beginning of the week. At the end of the week a short exam will be written on all presented topics.
High quality reports might be handed in as abstracts for an international photovoltaic conference. Preparation of such an abstract and paper is beyond the scope of the course itself but can be supported by the academic staff.</td></tr>
<tr><td colspan="4">Learning goals and qualifications
Based on the knowledge acquired in Photovoltaics 1 this course will deepen the knowledge of the students in PV. Furthermore students will study group work and learn to review a scientific topic in a short given time. The students will gain practice in oral presentation and written publication on a scientific level.</td></tr>
<tr><td colspan="4">Recommended reading
See Photovoltaics 1 – specific literature will be distributed at the beginning of the course</td></tr>
<tr><td colspan="4">Course prerequisites
Successful participation in Photovoltaics 1 or equivalent.</td></tr>
</table>

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** 27.01.2019	**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”

<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.
97021</td><td colspan="2">Module name
Management II</td><td>Semester/return
3rd Sem. / annual</td></tr>
<tr><td>Workload/presence
5 ECTS-P (150h/60 h)</td><td>Prerequisite module(s)
Management I</td><td>Follow-up module(s)
---</td><td>No. of participants
max. 25</td></tr>
<tr><td>Teaching form
Lectures, Guest lectures, Case study</td><td>Examination form
Seminar presentation, report/ manual or similar</td><td>Start date
11.11.2019</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">Teaching staff:</td></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td colspan="4">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</td></tr>
<tr><td colspan="4">Recommended reading
During the module materials will be made available via the learning platform ILIAS</td></tr>
<tr><td colspan="4">Course prerequisites
None.</td></tr>
</table>

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** 02.12.2019	**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:

-

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. 50
Teaching form Lectures, exercises, group work	**Examination form** Written exam (33%), Term paper + group work (67%)	**Start date** 07.01.2020	**Location** Tba.
Module coordinator: Stefan Pauliuk, PhD (stefan.pauliuk@indecol.uni-freiburg.de)			
Additional teaching staff Prof. Dr. Rainer Grießhammer, Kavya Madhu			

Syllabus

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

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

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

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

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

The module is interactive and encourages strong student participation.

Learning goals and qualifications

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

Recommended reading

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

Course prerequisites

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

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

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses This module is offered as elective to the MSc programmes MEG, Environmental Sciences, and Forest sciences			**Instruction Language** English
Module No. **97024**	**Module name** **Environmental and Energy Transition Law**		**Semester/return** 3rd Sem. / annual
Workload/presence 5 ECTS-P (150h/60h)	**Prerequisite module(s)** ---	**Follow-up module(s)** ---	**No. of participants** Max. 25
Teaching form Socratic lectures, group work, presentations	**Examination form** Group presentation (20%, 15 min.), indiv. written exam (40%, 2h), indiv. written report (40%, 3000 words)	**Start date** 07.01.2020	**Location** Tba.
Module coordinator: Jun.-Prof. Dr. Cathrin Zengerling, Prof. Dr. Errol Meidinger			
Additional teaching staff Guests tba			

Syllabus

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

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

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

Learning goals and qualifications

In this module students learn to:

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

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

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

Recommended reading

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

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

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

Course prerequisites

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<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.
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
27.01.2020</td><td>Location
t.b.a.</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: 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 This module is also available to students of the MSc programmes MEG, Geography, REM, Forest Sciences, and SSE.			**Instruction Language** English (German speaker available
Module No. 64090	**Module name** **Research Methods in Industrial Ecology**		**Semester/return** 3rd Sem. / annual
Workload/presence 5 ECTS-P (150h/60h)	**Prerequisite module(s)** ---	**Follow-up module(s)** ---	**No. of participants** Max. 25
Teaching form Seminars and project work	**Examination form** Term paper (80%), Oral presentation (20%)	**Start date** 27.01.2020	**Location** Tba.
Module coordinator: Stefan Pauliuk (stefan.pauliuk@indecol.uni-freiburg.de)			
Responsible teaching staff Stefanie Klose (stefanie.klose@indecol.uni-freiburg.de) and Gilang Hardadi (gilang.hardadi@indecol.uni-			

Syllabus

Understanding the challenges associated with sustainable development means understanding how the global consumption and production system works. Two important scientific tools that deliver such understanding are material flow analysis (studying how material flow through the techno-sphere) and environmental footprint analysis (studying the supply chain impacts of consumption baskets). Both tools are part of the industrial ecology field.

This module prepares the students for tackling two advanced research tasks in industrial ecology: First, the calculation of stock-flow relationships is explained and practiced in detail, answering questions like: “How big is the future outflow of waste products resulting from consumption in the past?” or “how many new cars need to be built every year so that the car fleet can grow to a certain size?”. Here, the participants learn how to develop their own computer models of the flows and stocks of materials and products and their evolution over time (i.e., dynamic stock modelling). Second, students learn how to calculate environmental footprints of products and regions using multi-regional input-output analysis, answering questions like “How big are the emissions from coal-based electricity associated with the consumption of consumer goods?” or “Which regions contribute most to the total German land footprint?”

Furthermore, there is a strong focus on critical thinking about model outcomes and uncertainty analysis.

Programming skills are required. Programming will be done both in Python (mostly) and R (to some extent).

Content:

This course is designed as advanced industrial ecology (IE) methods course. It course provides an in-depth treatment of the methods industrial ecologists have developed to study the socioeconomic metabolism. This course will be a good preparation for a master thesis in industrial ecology and will provide advanced knowledge on industrial ecology research methods and tools.

The objective of the course is to address common IE questions using different IE tools available. The goal of this course is to enable students to independently conduct quantitative research on industrial systems (industrial ecology).

The course consists of three parts, which will address the following topics:

Part 1: 1st week (4 days): *Responsible: Stefanie Klose*
A shift to ‘green’ technologies as well as to lower energy and material consumption is essential to come in line with climate goals and to alleviate global environmental pressures. However, these two strategies can contradict each other, since ‘green’ technologies are often more material intensive as their conventional counterparts. Studying future material consumption as a result of new technology phase-in and its effect on the environment is an important aspect of IE research. The first part of this course will focus on quantifying and evaluating material consumption resulting from major technological shifts in electricity generation to transform the energy supply and use system in light of the climate crisis. Furthermore, opportunities to close the loop of material cycles via recycling will be determined. This analysis, which is rooted in stock-flow dynamics, will be performed using the dynamic_stock_model module in Python and focus on case studies on either the energy supply sector or the consumer electronics sector. The students will:

+ Apply the dynamic_stock_model module and evaluate future material demand for different sustainable development trajectories.

+ Understand the importance of including the mining sector, material demand, and recycling in prospective scenarios for a sustainable future.

+ Learn how to use python tools to achieve a more holistic assessment of sustainable transition trajectories

Part 2: 2nd week (1 day in first week and 3 days in second week): *Responsible: Gilang Hardadi.*

Although developed countries have made efforts to reduce their territorial GHG emissions, there is little evidence that economic growth can be decoupled from environmental impacts at the global scale. Impact reductions in developed countries have occurred partly due to manufacturing outsourcing, particularly to China. To address the environmental impact leakages and to study decoupling more appropriately, consumption-based accounting is used to link impacts in the supply chain of goods and services to the final consumption point. Consumption-based accounting is also called the (environmental) footprinting approach. In this module, students will learn the state-of-the-art techniques to calculate environmental footprints of products and services at high levels of resolution and break them down into the contributions of individual industries and regions. The most important contributors to emissions along the entire supply chain will also be identified using structural path analysis (SPA). The students will:

+ learn about the theory behind consumption-based accounting and the concept “footprint of nations”

+ Learn how to perform an environmental footprint analysis using multi-regional input-output tables

+ Break down national footprints into different sectors and products

+ Apply regression analysis to study the possible correlation with different indicators such as GDP

Part 3: rest of 2nd and full 3rd week: Finally, students will apply the learned knowledge to their own case study (each student conducts and own case-study) using either stock dynamics or environmental footprinting. They will also perform a sensitivity analysis or Monte-Carlo simulation to get a better understanding of the prevalent uncertainties and dominant model parameters.

For this case study the students need to identify an interesting research question within the scope of the topics discussed during the first two weeks and make a quick assessment applying the tools presented in the first two parts of the course. The results of the case study work will be documented in a term paper and presented in the end. Students need to demonstrate critical thinking regarding what we actually can take out of the models/ results.

Course work will include seminars and the preparation of a term paper, both under supervision by members of the industrial ecology group. The term paper is an independent scientific piece of work, which will serve as basis for the course grade (80%), together with a short oral defense of the term paper (20%).

Learning goals and qualifications

After successful completion of the course, students will be able to:

- Conduct advanced research tasks in industrial ecology, in particular, the modelling of stock of materials and products over time (dynamic stock modelling) and the calculation and analysis of environmental footprints using multiregional input-output analysis.
- Analyse the uncertainty of the input data and model results
- Independently gain and improve skills on the central methods of industrial systems analysis, including material flow analysis, input-output analysis, and life cycle assessment
- Write a scientific text in German or English that adheres to the specific writing style of the environmental systems sciences

Recommended reading

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

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

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

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

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

Introduction to Python etc. Multiple web resources and library books available.

Course prerequisites

Participants must have participated in the Life Cycle Management or Nachhaltiges Energie- und Stoffstrommanagement courses before taking this course. This is a very programming intensive course, and programming skills are required as a prerequisite for entering this course. Participants must be familiar with at least one higher programming language. During the course, both Python (in form of Jupyter notebooks) and R will be used, ideally on the students' computers. Good skills in Matlab or C++, however, are also provide sufficient pre-knowledge to take this course as long as students are able to learn the Python and R elements.

We recommend that students, who are not yet familiar with the industrial ecology methods MFA and I/O Analysis yet, have a look at the open online course by Stefan Pauliuk, which covers a large fraction of the industrial ecology methods under http://www.teaching.industrialecology.uni-freiburg.de/. Students with knowledge of a higher programming knowledge other than R or Python are requested to make themselves familiar with the available and free R courses or online Python tutorials.

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses ---			**Instruction Language** English
Module No. **93952**	**Module name** **Energy System Operations**		**Semester/return** 2^{nd} Sem. / annual
Workload/presence 5 ECTS/(100h/50h)	**Prerequisite module(s)** Natural Resources and Conversion Technologies	**Follow-up module(s)** Elective modules	**No. of participants** Max. 75
Teaching form Lectures, exercises, excursion	**Examination form** Exam	**Start date** 20.04.2020	**Location** t.b.a
Module coordinator: Prof. Dr. Anke Weidlich			
Additional teaching staff:			

Syllabus

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

Learning goals and qualifications

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

Recommended reading

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

Course prerequisites

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

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses ---			**Instruction Language** English
Module No. **93220**	**Module name** **Introduction to Business Management**		**Semester/return** 2nd Sem. / annual
Workload/presence 5 ECTS-P (150h/60 h)	**Prerequisite module(s)** --	**Follow-up module(s)** Management II	**No. of participants** max. 75
Teaching form Lectures, Exercises, Seminar	**Examination form** Seminar presentation, written exam	**Start date** 11.05.2020	**Location** t.b.a
Module coordinator: Dr. Roderich von Detten (r.v.detten@ife.uni-freiburg.de)			
Additional teaching staff:			

Syllabus

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

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

2. Basics of management:

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

Teaching form:

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

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

Learning goals and qualifications

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

Recommended reading

There are several introductions to economy:

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

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

Course prerequisites

None.

<table>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses
---</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
93320</td><td colspan="2">Module name
Research Skills and Ethics for Sustainable Development</td><td>Semester/return
2nd Sem. / annual</td></tr>
<tr><td>Workload/presence
5 ECTS-P (150/60h)</td><td>Prerequisite module(s)
Scientific Framework for REM</td><td>Follow-up module(s)</td><td>No. of participants
max. 75</td></tr>
<tr><td>Teaching form
Lectures, Exercises, Seminar, presentations</td><td>Examination form
Written exam and term paper (pass or fail)</td><td>Start date
08.06.2020</td><td>Location
t.b.a</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: Dr. Cathrin Zengerling, Philipp Thapa</td></tr>
</table>

Syllabus

This module is the final course of the compulsory part of the REM programme. It deals with the introduction of sciences and scientific methodology. There are no prerequisites required for this course. In the first part of the module, students will be familiarized with the process of research including research strategy and cycle, literature review but also scientific misconducts and fraud. Students will get familiar with scientific citation and bibliography. A knowledge synthesis of a relevant scientific paper of medium complexity will be written and graded.

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

The ethics part of the module adds a normative and utopian perspective to the idea of socio-metabolic transitions. The focal double question is: “What future do we want, and why?” Students develop awareness for the diversity both of possible future visions and of the reasons and criteria that can be used to support or criticise their pursuance. They learn to distinguish between factual claims and normative appeals and to analyse their intertwinement in concepts such as development, economic growth, sustainability, biodiversity, or nature. They practise making normative arguments of their own and questioning those of others. Together, we discuss the main conceptions of sustainability and ethics and offer an introduction into environmental ethics, including the question whether we owe respect to (some) non-human beings. Students learn to consider “social technologies”, including ethics and lifestyles, as potential tools for sustainable development in addition to engineering solutions. (Main responsibility: Philipp Thapa)

Learning goals and qualifications

- Students will be able to understand the main goals and common methods of qualitative and quantitative research (including empirical methods and statistics)
- Students will be able to develop meaningful research questions (hypothesis) and to design studies to evaluate their hypothesis (including research design, data collection and analysis)
- Students will be able to communicate their research results among scientific community via scientific texts
- Scientific synthesis and writing skills, overview of research skills and application of research

skills for development of research proposal (knowledge synthesis and research gap, method choice and description, description of expected results and discussion items)

- Detailed knowledge about environmental ethics
- Awareness of the ethical aspects of sustainable development
- Basic knowledge of the main ethical approaches and normative argumentation skills

Recommended reading

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

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

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

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

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

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

Course prerequisites

None

Course M.Sc. Renewable Energy Engineering and Management			
Availability to other courses ---			**Instruction Language** English
Module No. xxxxx	**Module name** **Elective Hydropower**		**Semester/return** 2nd Sem. / annual
Workload/presence 5 ECTS-P (150/60h)	**Prerequisite module(s)** "Natural Resources and Conversion Technologies"	**Follow-up module(s)** ---	**No. of participants** Max. 30
Teaching form	**Examination form** Exercises and project work (short essay)	**Start date** 29.06.2020	**Location** t.b.a.
Module coordinators: Prof. Dr. Markus Weiler			
Additional teaching staff: Dr. Michael Rinderer			

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 This module is offered as elective to the MSc programmes MEG, MSc. Geographie des Globalen Wandels; MSc. Environmental Sciences</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
93936</td><td colspan="2">Module name
Global Sustainability Transformations in Local Contexts</td><td>Semester/return
3rd Sem. / annual</td></tr>
<tr><td>Workload/presence
5 ECTS-P (150h/60h)</td><td>Prerequisite module(s)
---</td><td>Follow-up module(s)
---</td><td>No. of participants
Max. 25</td></tr>
<tr><td>Teaching form
Lectures, group work, presentations</td><td>Examination form
Essay (indiv., 2000 words), case study (group, 3000 w)ords, present. (group, 15 min.)</td><td>Start date
29.06.2020</td><td>Location
Tba.</td></tr>
<tr><td colspan="4">Module coordinator: Jun.-Prof. Dr. Cathrin Zengerling, Dr. Benedikt Schmid</td></tr>
<tr><td colspan="4">Additional teaching staff
Guests tba</td></tr>
</table>

Syllabus

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

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

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

Learning goals and qualifications

In this module students:

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

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

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

Recommended reading

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

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

Course prerequisites

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<table>
<tr><td colspan="4">Course
M.Sc. Renewable Energy Engineering and Management</td></tr>
<tr><td colspan="3">Availability to other courses
---</td><td>Instruction Language
English</td></tr>
<tr><td>Module No.
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
20.07.2020</td><td>Location
T.b.a.</td></tr>
<tr><td colspan="4">Module coordinator: Dr. Thomas Fillbrandt</td></tr>
<tr><td colspan="4">Additional teaching staff: Dr. Sebastian Paczkowski</td></tr>
</table>

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
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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. 40</td></tr>
<tr><td>Teaching form
Lectures, exercises, excursion</td><td>Examination form
Poster presentation</td><td>Start date
20.07.2020</td><td>Locations
T.b.a.</td></tr>
<tr><td colspan="4">Module coordinator: PD Dr. Dirk Schindler (dirk.schindler@meteo.uni-freiburg.de)</td></tr>
<tr><td colspan="4">Additional teaching staff: Christopher Jung, M.Sc. (christopher.jung@mail.unr.uni-freiburg.de)</td></tr>
</table>

Syllabus

The Wind Energy module will give the students deep understanding of the meteorological potential, geographical potential, technical potential, economic potential and implementation potential of wind energy.

The module structure is basically project-oriented including lectures, GIS and modeling exercises and an excursion.

In the module the following topics will be discussed:

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

Learning goals and qualifications

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

Recommended reading

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

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

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

Course prerequisites

Basic knowledge of wind energy.

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** 10.08.2020	**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.			