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Modules for Sustainable Renewable Energy Technologies

Mastermodule

pre011 - Fundamentals of Renewable Energy

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Applicability of the module
- Sustainable Renewable Energy Technologies (Master) > Mastermodule

Responsible persons
- Agert, Carsten (Authorized examiners)
- Günther, Andreas (Authorized examiners)
- Holtorf, Hans-Gerhard (Authorized examiners)
- Jimenez Martinez, Cuauhtemoc Adrian (Authorized examiners)
- Knecht, Robin (Authorized examiners)
- Torio, Herena (Authorized examiners)
- Malz, Simone (Authorized examiners)
- Ziethe, Paul (Authorized examiners)

Prerequisites

Skills to be acquired in this module

After successful completion of the module students should be able to:

- identify their competence and incompetence with respect to the study of renewable energies
- describe basic knowledge from a wide field of disciplines as required for renewable energies
- perform laboratory measurements in a university environment according to scientific standards
- analyse and interpret measurement results using relevant and widely used software tools
- work and communicate their results with international and interdisciplinary partners
- critically discuss basic principles of current mainstream economics
- distinguish between the classical, neo-classical and selected heterodox economics and relate those approaches to the historic economic development
- distinguish and evaluate the peculiarities of selected energy markets and its regulatory frameworks

Module contents

The module is designed to give students a solid foundation to successfully start the MSc programme. The content from the field of Physics, Mathematics as well as Electrical and Mechanical Engineering aims to provide a homogenous foundation for the study of renewable energies via lectures and laboratory experiments. With an introduction into Socio-economics students will learn about the principles of mainstream economics, the peculiarities of energy markets and will get insight into some selected heterodox economic perspectives.

Primers (Lecture & Exercises ? 60 h workload)

- Mathematics
- Programming
- Modelling
- Electronic Power Systems
- Semiconductor Physics
- Material Characterization
- Thermodynamics
- Fluid Dynamics

Laboratories (Theoretical/practical Seminar ? 120 h workload)
- Introductory Laboratory
- Interaction Light and Matter
- Heat Transfer
- Fluid Dynamics
- Storage Technologies

Introduction to Socio-economics (Lecture & Seminar ? 90 h workload)
- Scarcity, market
- Supply and demand
- Equilibrium
- Elasticity
- Incentives, free market, role of the state
- Peculiarities of energy markets and corresponding regulatory frameworks
- Limitations of mainstream economics
- Selected heterodox economics

Reader’s advisory

Links
Languages of instruction German, English

Duration (semesters) 1 Semester

Module frequency

Module capacity unlimited

Modulelevel / module level MM (Mastermodul / Master module)

Modulart / typ of module Pflicht / Mandatory

Lehr-/Lernform / Teaching/Learning method

Vorkenntnisse / Previous knowledge

Examination Time of examination Type of examination
Final exam of module 2 Prüfungsleistungen: Fachpraktische Übungen (Versuchsprotokolle und Übungsaufgaben, Gewicht: 75%) und entweder Hausarbeit (10-15 Seiten) oder Präsentation (15-20 min, Gewicht: 25%) 2 Prüfungsleistungen: Fachpraktische Übungen (Versuchsprotokolle und Übungsaufgaben, Gewicht: 75%) und entweder Hausarbeit (10-15 Seiten) oder Präsentation (15-20 min, Gewicht: 25%)

Course type Comment SWS Frequency Workload of compulsory attendance
Course or seminar 2 SoSe und WiSe 28
Exercises 4 SoSe und WiSe 56

Total time of attendance for the module 84 h
**pre021 - Energy Resources and Systems**

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<tr>
<td>Responsible persons</td>
<td>Torio, Herena (Authorized examiners)</td>
</tr>
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</table>

**Prerequisites**

**Skills to be acquired in this module**

After successful completion of the module students should be able to:

- characterise the global energy system and analyse the structure and constraints of today's energy system
- explain the availability and connection between solar and wind energy
- identify the problems and challenges of energy supply due to fluctuating energy resources with varying and seasonal load profiles
- relate the solar irradiance conversion process as well as the atmospheric radiation balance of the earth to Wind Energy Meteorology

**Module contents**

This module will give an overview on the global energy system and the challenges of energy supply due to fluctuating energy resources with varying and seasonal load profiles.

Energy Meteorology (Lecture ? 90 h workload)

**Section I: Solar Irradiance**

- Radiation Laws
- Solar Geometry
- Interaction of solar irradiance with the atmosphere
- Radiation Climatology
- Solar Radiation Model
- Statistical Properties of Solar Irradiance
- Measuring devices to ascertain Solar Radiation balance
- Satellite-supported data acquisition to assess Solar Irradiance

**Section II: Wind Flow**

- Origin and Potential of atmospheric energy movements, Heat balance of the atmosphere
- Physical laws of atmospheric flow
- Wind circulation in the atmosphere, Local Winds
- Wind flow in atmospheric layers (Vertical Structure, Ekman Layer)
- Assessment of Wind potential (European Wind Atlas: Model, Concept
- Wind Measurements

Energy Systems (Lecture ? 90 h workload)

- Definitions, separation electrical - thermal energy use
- Resources & reserves
- Energy system analysis: Efficiencies at various levels of the energy chain; Exergy analysis
- Energy scenarios
- Climate Change
- Advanced (power plant) technologies for conventional fuels
- Electric power systems with large shares of renewables

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pre031 - Renewable Energy Technologies I

Module label                  Renewable Energy Technologies I
Module code                   pre031
Credit points                 12.0 KP
Workload                      360 h
Applicability of the module   Sustainable Renewable Energy Technologies (Master) > Mastermodule
Responsible persons
Agert, Carsten (Authorized examiners)
Knecht, Robin (Authorized examiners)
Hölling, Michael (Authorized examiners)
Holtorf, Hans-Gerhard (Authorized examiners)
Torio, Herena (Authorized examiners)
Wark, Michael (Authorized examiners)
Pehiken, Alexandra (Authorized examiners)
Steinberger-Wickens, Robert (Authorized examiners)

Prerequisites

Skills to be acquired in this module

After successful completion of the module students should be able to:

- critically evaluate and compare three major Renewable Energy conversion processes and technologies: photovoltaics, wind energy and one out of three of solar thermal energy, biomass energy or hydro power.
- critically appraise various electrochemical storage processes and the respective storage techniques
- analyse various system components and their interconnections within a complex Renewable Energy supply system.
- evaluate the Renewable Energy supply systems' operational size and efficiency.
- critically evaluate non-technical impact and side effects when implementing renewable energy supply systems

Module contents

This module will give an overview over a selection of the major renewable energy technologies and some possibilities of their storage. The focus is on the scientific principles of components and the technical description of the components. Further detailed system analysis will be presented in other modules.

Photovoltaics (Lecture ? 90 h workload)

Physics of PV:

- Basic and most important properties of solar radiation related to photovoltaics
- PV cells basics: Fundamental physical processes in photovoltaic materials
- Characterisation and basic modelling of solar cells

Component Description:

- PV generator
- Charge controller
- Inverter
- Balance of system components

System Description

- Grid Connected System
- Stand Alone System

Basics of Wind Energy (Lecture ? 90 h workload)

- Wind characterization and anemometers
- Aerodynamic aspects of wind energy conversion
- Wind turbine performance
- Design of wind turbines
- Dimensional analysis and pi-theorem

Fuel Cells & Energy Storage (Lecture ? 90 h workload)

- Fundamentals of electrochemistry and thermodynamics, energy and environmental balances
- Basics of hydrogen production - starting materials, processes, efficiencies, environmental impacts
- Basics of fuel cells function, materials, construction, systems, applications
- Fundamental setup of most common battery types
- Fundamental chemical reactions in these batteries
- Operational characteristics, weir processes and service lives of these batteries.

Solar Thermal Energy, Biomass Energy, Hydro Power

Students select one out of the three units:

a. Solar Thermal Energy (90 h workload)

b. Biomass Energy (90 h workload)

c. Hydro Power (90 h workload)

In the third semester the other two of the three units will be selected in the module Renewable Energy Technology II.

Solar Thermal Energy (Seminar & Exercises ? 90 h workload)

- Assessment of solar thermal ambient parameters: regional global, diffuse, reflected solar radiation on horizontal and on tilted plane, ambient temperature
- Solar thermal collectors
- Solar thermal heat exchangers
- Solar thermal storages
- Solar thermal systems and their operation
- Characterization of solar thermal systems

Biomass Energy (Lecture ? 90 h workload)

- Energy mix overview; gas, heat, electricity, Pros & Cons of biomass
- Chemical composition of biomass: sugar, cellulose, starch, fats, Oils, proteins, lignin
- Natural photosynthesis in plants: chemical storage of solar energy; general mechanisms
- Chemistry & Biology (microorganism) of Biogas Technology
- Conversion processes of biomass: classification, main pathways
- Introduction to catalysis used in biomass conversion
- Chemical fuels (chemical energy storage) from biomass, routes to platform chemicals and separation processes
- Technology concepts for bioenergy usage
- Introduction into economical and legal constraints

Hydro Power (Seminar & Exercises ? 90 h workload)

- Theoretical background ? general hydraulic terms, Bernoulli Equation, Major Empirical Formulae and their backgrounds
- Water Resource ? catchment area, seasonal precipitation, flow duration curve, dam, & run off river
- Powerhouse ? penstock, water hammer, cavitation, tailrace
- Turbines ? main types of turbines, their characteristics & their components
- Ocean Power Overview

Reader’s advisory

Links
Languages of instruction
German, English

Duration (semesters)
1 Semester

Module frequency

Module capacity
unlimited

Modullevel / module level
BC (Basiscurriculum / Base curriculum)

Modulart / typ of module
Pflicht / Mandatory

Lehr-/Lernform / Teaching/Learning method

Vorkenntnisse / Previous knowledge

Examination
Time of examination
Type of examination
Final exam of module
2 Prüfungsleistungen: Klausur (3h, Gewicht 75%) sowie Referat (15 min. Präsentation, 15 Seiten Bericht, Gewicht 25%).

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Total time of attendance for the module
112 h
**Module code**

pre041

**Credit points**

6.0 KP

**Workload**

180 h

**Applicability of the module**

- Sustainable Renewable Energy Technologies (Master) > Mastermodule

**Responsible persons**

Torio, Herena (Authorized examiners)

Agert, Carsten (Module responsibility)

Torio, Herena (Module responsibility)

**Prerequisites**

**Skills to be acquired in this module**

After successful completion of the module students should be able to:

- analyse, and critically compare and evaluate selected sustainability concepts and strategies addressing renewable energy systems
- critically appraise and analyse the principles and implications of selected scientific methods and theories for a sustainable energy supply
- critically evaluate the suitability and meaningfulness of different sustainability indicators, theories, methods and practices regarding their role and impact for developed countries, on the one hand, and developing countries, on the other
- perform an integral assessment, involving several relevant aspects related to the sustainability of a particular real-life renewable energy project as well as identify the main barriers, potentials and driving factors for improving it
- perform a literature review on selected sustainability approaches to a professional standard and extract the main related conclusions, and arguing critically on them
- present data and information both verbally and in the written form, including quotation to a professional standard

**Module contents**

The module “Sustainability of RE Systems” provides the theoretical background for understanding main concepts and interdisciplinary scientific methods from the context as well as their role in the sustainability debate.

**Sustainability Seminar (Lecture & Seminar ? 180 h workload)**

- Strategies and dimensions in sustainability research and discussion: efficiency, consistency and sufficiency, as well as related concepts (e.g. rebound)
- Growth/De-growth and decoupling of growth and emission
- Life-cycle analysis
- Thermodynamic methods: exergy, EROI and related approaches
- Social indicators and their relation to energy use
- Economic indicators and related paradigms in the context of energy consumption
- Resilience and its operationalisation for energy systems
- Methods for developing and assess socio-technical scenarios

**Reader's advisory**


Links

Language of instruction: English
Duration (semesters): 1 Semester
Module capacity: unlimited
Module level / module level: MM (Mastermodul / Master module)
Modulart / typ of module: Pflicht / Mandatory

Vorkenntnisse / Previous knowledge

Examination: Time of examination: At the end of the lecture period (presentation) and end of semester (report)
Type of examination: 1 Examination: Presentation of a Paper (presentation - 20 minutes and written report 15 pages) or Term Paper (15 pages)

Course type: Lecture
Comment: SWS: Frequency: Workload of compulsory attendance
2: WiSe: 28
Seminar: SoSe und WiSe: 28

Total time of attendance for the module: 56 h
## pre051 - Renewable Energy Systems Laboratory and Modelling

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### Applicability of the module
- Sustainable Renewable Energy Technologies (Master) > Mastermodule

### Responsible persons
- Günther, Andreas (Authorized examiners)
- Holtorf, Hans-Gerhard (Authorized examiners)
- Jimenez Martinez, Cuauhtemoc Adrian (Authorized examiners)
- Torio, Herena (Authorized examiners)
- Knipper, Martin (Authorized examiners)
- Peinke, Joachim (Module responsibility)
- Knipper, Martin (Module responsibility)

### Prerequisites

### Skills to be acquired in this module

After successful completion of the module students should be able to:
- implement as well as critically analyse and discuss models and their limitations using various methods
- develop research questions and approaches to answer them
- perform laboratory measurements or simulations in a university environment
- analyse and interpret their results using relevant and widely used software tools
- work and communicate their results with international and interdisciplinary partners according to scientific standards

### Module contents

In this module the students obtain the knowledge and skills on programming, modelling and critically analysing simulations and apply those in a topic on renewable energies of their choice. Students have the choice to simulate specific renewable energy components or systems which are later investigated in hands-on laboratories. Through this students learn to critically discuss the results of their simulations and compare them to real measurements as well the results from differently implemented simulations from which they deduce the limits and validity of the respective models.

Modelling and Simulation of Renewable Energy Systems (Lecture & Seminar ? 90 h workload)

- numerical concepts
- differential equations
- discrete models
- statistical modeling
- algorithms to develop simulations
- building a simple model from the field of renewable energies
- various tools to implement and critically analyse the performance and limits of a model
- examples of various simulation approaches
Laboratory on Renewable Energy Systems (Theoretical?practical Seminar ? 90 h workload)

- Theory, Hands-on experience and reporting on either:
  - Improved Cook Stoves
  - Wind Energy Systems
  - Solar Home Systems
  - Meteorological Resource Assessment
- Student conference on the Performance of Renewable Energy Systems

Reader's advisory

Links

Languages of instruction

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Teaching/Learning method

Lecture and Laboratory

Previous knowledge

Exam

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<td>Student conference at the end of the semester</td>
<td>1 Examination: Conference contribution approx. 15 min presentation and approx. 8 pages of written discussion</td>
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Course type

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Total time of attendance for the module

56 h
pre071 - Internship

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Applicability of the module
- Sustainable Renewable Energy Technologies (Master) > Mastermodule

Responsible persons
- Torio, Herena (Authorized examiners)
- Agert, Carsten (Module responsibility)
- Torio, Herena (Module responsibility)

Prerequisites

Skills to be acquired in this module

After successful completion of the module students should be able to:

- evaluate and critically reflect on his/her two months working experience
- critically appraise and compare professional working in different working environments, i.e. business, research, development organisation
- conclude whether he/she intends to work further in this particular field of Renewable Energy for his/her master thesis
- present data and information both verbally and in the written form to a professional standard (i.e. scientific report writing, presentation and quotation)

Module contents

External Internship (180 h workload)

The ‘External Internship’ is an approximately two-month stay in companies, consultancies, international development organisations or research institutes, normally outside Oldenburg University. Students stay for and perform in accordance with some basic principles one or several tasks, related to the activities/business of the respective host organisation. The training, normally situated in the break between the first and second semester of the postgraduate programme, can either help to prepare for the six-month Master Thesis Project, which will follow after the third term. Otherwise, it can also be used as a supplementary or complementary experience in an additional field of interest. Organisations that take PPRE students for an internship may have their own regulations with respect to internships, which apply anyway. The external Internship will be concluded by a report (ca. 20 pages).

The University of Oldenburg requests to fulfil a few requirements for the internship:

- The university needs an acceptance letter (incl. contact details of local supervisor and topic of internship) from the host organisation prior to start the internship.
- The duration of the training should enable students to return to university at the beginning of summer term classes.
- Weekly full-time workload is required. However, it should not exceed local standards.
- Students are asked to hand in a report (approx. 20 pages) on their training, comprising a description of the host organisation, planned and performed tasks, perspectives for a thesis project, and give a presentation in the Internship Seminar in the summer term.
- If the host organisation demands a certain format of the report, the student has to comply.
- A short feedback by the local supervisor about the performance of the student during the internship is requested and recommended, but not compulsory.

Internship Seminar (90 h workload)
Presentation (20 minutes) of the host organisation, the task(s) and experiences

Reader’s advisory

Links

Language of instruction English

Duration (semesters) 1 Semester

Module frequency jährlich

Module capacity unlimited

Modullevel / module level MM (Mastermodul / Master module)

Modulart / typ of module Pflicht / Mandatory

Lehr-/Lernform / Teaching/Learning method

Vorkenntnisse / Previous knowledge

Examination Time of examination Type of examination

Final exam of module At the end of the lecture period and during the semester (presentation) 1 Examination: E-Portfolio including a (presentation (incl. Discussion - 20min.) and reflection activities (short reflection summary, SWOT analysis)

Course type Comment SWS Frequency Workload of compulsory attendance

Seminar 2 SoSe und WiSe 28

Practical training 4 SoSe und WiSe 56

Total time of attendance for the module 84 h
pre061 - Renewable Energy Complementary Topics

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**Responsible persons**

Agert, Carsten (Authorized examiners)
Heinemann, Detlev (Authorized examiners)
Gütay, Levent (Authorized examiners)
Holtorf, Hans-Gerhard (Authorized examiners)
Kühn, Martin (Authorized examiners)
Lukassen, Laura (Authorized examiners)
Siebenhüner, Bernd (Authorized examiners)
Schmidt, Andreas Hermann (Authorized examiners)
Stoevesandt, Bernhard (Authorized examiners)
Lehnhoff, Sebastian (Authorized examiners)
Aßmuth-Düster, Heidemarie (Authorized examiners)
Kobusch, Ulrich (Authorized examiners)
Tjarks, Claudia (Authorized examiners)

**Prerequisites**

**Skills to be acquired in this module**

After completing the module students will be able to:

- describe basic knowledge in two of a wide field of disciplines (technical, scientific, social, political, transferrable, language) as required for the implementation of renewable energy
- critically discuss basic principles of the implementation of renewable energy
- justify their personal decision on educational fields for their career development

**Module contents**

The module is designed to give students an outlook on fields which have not been covered so far in their previous lectures and specialization modules. The content from the fields of technical, scientific, social, political, transferrable, language disciplines is offered for tailoring the personal education for the planned careers. All units are 3CP units.

- Advanced Solar Energy Meteorology (Dr. Detlev Heinemann) (Lecture ? 90 h workload)
- Advanced Wind Energy Meteorology (Dr. Detlev Heinemann) (Lecture ? 90 h workload)
- Photovoltaic Systems (Hans-Gerhard Holtorf PhD) (Lecture ? 90 h workload)
- Physical Basics of Photovoltaics (Dr. Michael Richter) (Lecture ? 90 h workload)
- Future Power Supply Systems (Prof. Dr. Carsten Agert) (Lecture ? 90 h workload)
- Biomass in Developing Countries (Andreas Günther) (Lecture ? 90 h workload)
- Smart Grids Lecture (Prof. Dr. Sebastian Lehnhoff) (Lecture ? 90 h workload)
- Smart Grids Seminar (Prof. Dr. Sebastian Lehnhoff) (Seminar ? 90 h workload)
- Fluid Dynamics II (Prof. Dr. Joachim Peinke) (Lecture ? 90 h workload)
- Computational Fluid Dynamics I (Dr. Bernhard Stoevesandt) (Lecture ? 90 h workload)
- Wind Physics Measurement Project (Prof. Dr. Martin Kühn, Andreas Hermann Schmidt) (Project ? 90 h workload)
- Wind Energy Applications ? from Wind Resource to Wind Farm Operations (Dr. Hans-Peter Waldl) (Lecture ? 90 h workload)
- Ecological Economics (Prof. Dr. Bernd Siebenhüner) (Lecture ? 90 h workload)
- International Environmental Governance (Prof. Dr. Bernd Siebenhüner) (Lecture ? 90 h workload)
- Project Management (Ulrich Kobusch) (Project ? 90 h workload)
- Language Course (Heidemarie Aßmuth-Düster) (Lecture ? 90 h workload)
- Conflict Management (Claudia Tjarks) (Seminar ? 90 h workload)
- Working in International Teams (Claudia Tjarks) (Seminar ? 90 h workload)
- German language courses

Reader's advisory

Languages of instruction
German, English

Module frequency

Module capacity
unlimited

Module level / module level
BC (Basiscurriculum / Base curriculum)

Module type / type of module
Wahlpflicht / Elective

Lehr-/Lernform / Teaching/Learning method

Vorkenntnisse / Previous knowledge

Final exam of module

Examination
Time of examination
Type of examination
2 Prüfungsleistungen: Das Modul ist unbenotet, jedoch müssen 2 der möglichen Kurse mindestens als 'bestanden' gewertet werden um das Modul zu bestehen. Mögliche Prüfungsformen sind: Klausur (1 h), mündliche Prüfung (20 min), Referat (10 Seiten Ausarbeitung + 10 Minuten Präsentation), Hausarbeit (max. 20 Seiten), fachpraktische Übung (max. 8), Seminararbeit (max. 20 Seiten), Portfolio, Präsentation (15 min.) In Seminaren wird Aktive Teilnahme (siehe Ergänzung zu § 9 Abs. (6) ) gefordert.

Course type
Comment
SWS
Frequency
Workload of compulsory attendance
Lecture
2
SoSe und WiSe
28
Seminar and tutorial
2
SoSe und WiSe
28

Total time of attendance for the module
56 h
pre081 - Renewable Energy Project

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Applicability of the module
- Sustainable Renewable Energy Technologies (Master) > Mastermodule

Responsible persons
- Holtorf, Hans-Gerhard (Authorized examiners)
- Wollenhaupt, Matthias (Authorized examiners)
- Knipper, Martin (Authorized examiners)
- Torio, Herena (Authorized examiners)
- Wollenhaupt, Matthias (Module responsibility)
- Holtorf, Hans-Gerhard (Module responsibility)

Prerequisites

Skills to be acquired in this module

In the module Renewable Energy Project students merge the acquired scientific knowledge on different RE technologies and the concepts and methodologies they have gained in the different related disciplines and they transfer their competences to solve a real life project.

After successful completion of the module students should be able to:

- appraise the challenge of a given energy service supply problem
- assess given data of the situation of the energy service supply problem
- discriminate between valuable and less valuable input data, necessary and unnecessary data
- judge and then decide on methodologies to apply to generate a solution
- develop and then recommend a technical, economic and social solution for an energy service supply system
- explain, justify and defend the developed solution

Module contents

This module trains students to apply the knowledge acquired in previous lectures to a real life problem.

Case Study (Seminar ? 180 h workload)

Students need to

- Evaluate the state of the art at the Case Study’s project site
- Describe the energy services demanded
- Determine the energy demand to supply these services in hourly and seasonal course of time
- Design the energy supply system based on different technologies for this energy demand
- Technically & economically optimise generator size, storage size, dumped energy and unmet energy
- Write a final report for the stakeholder involved
- Present the findings to the stakeholders involved
- Solve challenges of working in an international group in order to generate a solution (project
Excursion (Excursion ? 90 h workload)

The excursion refers to the case study project. Within the excursion, students collect necessary information for the completion of the Case Study itself.

Students prepare, manage and document the excursion by

- Setting up a list of institutions to be visited
- Plan the excursion route and excursion schedule
- Negotiate the necessary appointments
- Perform the excursion
- Prepare all participants for the appointments with the institutions
- Conduct the appointments
- Document the appointments
- Draw necessary conclusions for the Case Study from the excursion

Specifically, the Excursion will contribute to the PPRE students' bonding amongst one another and with other students at the university of Oldenburg (specifically EP, Phy, SEM).

Furthermore, it enables insights into institutions dealing with Renewable Energy on multiple levels.
<table>
<thead>
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<td></td>
<td></td>
<td>Presentation of a Paper - Case Study -</td>
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<td>30min presentation + 10pages report</td>
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**Total time of attendance for the module** 84 h
pre111 - Photovoltaic Physics

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<tr>
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<tr>
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<tr>
<td>Responsible persons</td>
<td>Gültey, Levent (Authorized examiners)</td>
</tr>
<tr>
<td></td>
<td>Knecht, Robin (Authorized examiners)</td>
</tr>
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</table>

Prerequisites

Skills to be acquired in this module

After successful completion of the module students should be able to:

- describe schematically the events around the pn-junction under bias in the dark and under illumination
- calculate the width of the space charge region
- use solar cell data sheets in their professional career
- discuss the concepts of solar cell materials, design and optimization
- choose a PV technology for a given project

Module contents

This specialization module covers the physics of photovoltaics. The behaviour of solar cells is discussed from a fundamental physical point of view to explain the differences in performance and limits of various photovoltaic materials. Students learn how solar cells function, are designed and optimized.

Physical Basics of Photovoltaics (Lecture & Exercises ? 180 h workload)

- Optical and electronical properties of semiconductors, light absorption
- Charge carrier generation/recombination/life time
- Charge carrier transport across the pn-junction in equilibrium and under light and voltage bias,
- Transport equations,
- Current-voltage characteristics, efficiency
- Quantum efficiency
- Design concepts to optimize the efficiency
- Overview of the most important PV technologies

Reader's advisory

Links

Languages of instruction  German, English
Duration (semesters)  1 Semester
Module frequency

Module capacity  unlimited
Modulelevel / module level  BC (Basiicurriculum / Base curriculum)
Modulart / typ of module  Wahlpflicht / Elective

Vorkenntnisse / Previous knowledge
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**Total time of attendance for the module**  
56 h
pre112 - Photovoltaics Systems & Solar Energy Meteorology

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Applicability of the module
- Sustainable Renewable Energy Technologies (Master) > Mastermodule

Responsible persons
- Agert, Carsten (Authorized examiners)
- Heinemann, Detlev (Authorized examiners)
- Holtof, Hans-Gerhard (Authorized examiners)
- Stoevesandt, Bernhard (Authorized examiners)

Prerequisites

Skills to be acquired in this module

After successful completion of the module students should be able to:

- explain the concepts of physical processes governing the surface solar irradiance available for solar energy applications
- model the solar radiation and show their expertise in application, adaptation and development of models
- discuss state-of-the-art-methods in satellite-based irradiance estimation and solar power forecasting
- categorize and feature different PV systems (PV on-grid, PV off-grid, PV pumping, PV-hybrid)
- explain concepts behind PV system design
- explain the operation principles of PV systems

Module contents

This specialization module covers more in-depth topics concerning photovoltaics systems and solar energy meteorology. Based on their knowledge about the solar resource and photovoltaic behaviour students learn to design a photovoltaic system for various environmental conditions and predict its performance.

Solar Energy Meteorology (Lecture ? 90 h workload)

- Physics of radiative processes in the atmosphere
- Physical modelling of atmospheric radiative transfer (incl. computing tools)
- Solar irradiance modelling for solar energy applications
- Solar spectral irradiance: Theory & relevance for solar energy systems
- Satellite-based estimation of solar irradiance
- Solar irradiance (& solar power) forecasting
- Solar radiation measurements: Basics & setup of high-quality measurement system

Photovoltaic Systems (Lecture ? 90 h workload)

- Detailed description of involved balance of system components (e.g. inverter, charge controllers)
- System Operation
- Detailed System Design ? from meteorological input across component rating to energy service output

Reader's advisory
## Links

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<tr>
<th>Languages of instruction</th>
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### Lehr-/Lernform / Teaching/Learning method

#### Examination / Previous knowledge

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### Course type

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### Total time of attendance for the module

56 h
pre121 - Wind Energy Converters & Fluid Dynamics

<table>
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<td>Lukassen, Laura (Authorized examiners)</td>
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</table>

Prerequisites

Skills to be acquired in this module

After successful completion of the module students should be able to:

- Resolve fluid dynamic problems occurring in the field of wind energy converters
- Measure characteristics of wind energy converters
- Evaluate wind energy related measurements
- Interpret such measurements gained in the field of wind energy applications
- Critically evaluate measured data

Module contents

This module allows students to access wind energy from the hydrodynamic view angle of the wind resource.

Computational Fluid Dynamics (CFD) I (Lecture ? 90 h workload)

- Navier-Stokes equations
- filtering / averaging of Navier-Stokes equations
- introduction to numerical methods
- finite-differences
- finite-volume methods
- linear equation systems
- incompressible flows
- compressible flows
- C++

Computational Fluid Dynamics (CFD) II (Lecture ? 90 h workload)

- Introduction to different CFD and Large Eddy Simulation (LES) models, such as OpenFOAM, PALM
- Application of these CFD models to defined problems from rotor aerodynamics and the atmospheric boundary layer
- Navier-Stokes solvers: RANS, URANS, LES, DNS
- turbulent flows
- efficiency and accuracy

Fluid Dynamics II (Lecture ? 90 h workload)

The unit is oriented towards research based topics:

- Modeling turbulence \& CFD methods: Reynolds Equation, Eddy viscosity, Boundary layers flows, Large Eddy Simulation
- Models of idealised turbulence and statistical methods: Hierarchies of moment equations, turbulence hypothesis, fine structure of turbulence, multi-fractal models, other.
- Models of turbulence: cascade models and stochastic models and other hypothesis

Wind Physics Measurement Project (Project ? 90 h workload)

Case study like problems based on real world data will be solved on at least four important aspects in wind physics. The course will comprise lectures and assignments as well as self-contained work in groups of 3 persons.

The content consists of the following four main topics, following the chronological order of the work process:

- Data handling:
  - measurement technology
  - handling of wind data
  - assessment of measurement artefacts in wind data
  - preparation of wind data for further processing

- Energy Meteorology:
  - geographical distribution of winds
  - wind regimes on different time and length scales
  - vertical wind profile
  - distribution of wind speed
  - differences between onshore and offshore conditions.

- Measure \& Correlate \& Predict (MCP):
  - averaging of wind data
  - long term correlation and long term correction of wind data
  - sources of long term wind data.

- LIDAR (Light Detection and Ranging):
  - analyses and conversion of data from LIDAR measurements

Reader's advisory

Links

Languages of instruction
German, English

Duration (semesters) 1 Semester
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| Total time of attendance for the module | 112 h |
pre131 - Design and Simulation of Wind Turbines

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<td>Waldl, Hans-Peter (Authorized examiners)</td>
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</table>

Prerequisites

Skills to be acquired in this module

After successful completion of the module students should be able to:

- critically contribute to the discourse on wind energy design and simulation
- explain and evaluate technical details of a wind energy converter
- decide and to defend a design of a wind energy converter
- recommend on technical details of a wind energy converter
- transfer their knowledge to more complex topics such as simulation and measurements of dynamic loads
- assess different aspects of wind energy farms by modelling, comparison, explanation of wind energy potential, wind energy farm’s output, power curves, wind energy project development
- assess in detail influences of meteorological/climatological aspects on the performance of wind power systems
- summarize physical processes governing atmospheric wind flows
- value atmospheric boundary layer flow relevant for wind power conversion
- argue methods for wind resource assessment and forecasting

Module contents

Content of the module:

The module accesses wind energy from a rather technical approach.

Design of Wind Energy Systems (Lecture & Project ? 180 h workload)

- Calculation of the aerodynamics of wind turbines using the blade element momentum theory,
- Specific design situations for wind turbines,
- Estimation of the influence of dynamics of a wind turbine, especially in the context of fatigue loads,
- Aeroelastic simulation of wind turbines
- Annual Energy Production (AEP)
- Design of a commercial (equivalent) wind turbine

Advanced Wind Energy Meteorology (Lecture ? 90 h workload)

- Atmospheric Boundary Layer (turbulence, vertical structure, special BL effects)
Wind Energy Applications - from Wind Resource to Wind Farm Operations (Lecture 90 h workload)

- Evaluation of Wind Resources
  - Weibull Distribution
  - Wind velocity measurements to determine energy yield
  - Basics of Wind Atlas Analysis and Application Program (WAsP) Method, Partial models using WAsP
  - Measure-Correlate-Predict (MCP) Method of long term corrections of wind measurement data in correlation to long term reference data
  - Conditions for stable, neutral and instable atmospheric conditions
  - Wind yield from wind distribution and the power curve
  - Basics in appraising the yearly wind yield from a wind turbine.

- Wake Effect and Wind Farm
  - Recovery of original wind fields in the downstream of wind turbines
  - Basics of Rise Models
  - Spacing and efficiency in wind farms
  - Positive and Negative Effects of Wind Farms

- Wind Farm Business
  - Income from the energy yield from wind farms
  - Profit optimization by increase of energy production
  - Wind farm project development
  - Wind farm operation and
  - Surveillance of power production vs. wind climate, power curves, and turbine availability

Reader's advisory

Links
Languages of instruction German, English
Duration (semesters) 1 Semester
Module frequency
Module capacity unlimited
Modullevel / module level BC (Basicscurriculum / Base curriculum)
Modulart / typ of module Wahlpflicht / Elective
Lehr-/Lernform / Teaching/Learning method
Vorkenntnisse / Previous knowledge
Examination Time of examination Type of examination
Final exam of module 1 Prüfungsleistung: Klausur (3h) oder Präsentation (30 min.) oder mündliche Prüfung (45 min.) oder fachpraktische Übungen (max. 10) oder Hausarbeit (max. 30 Seiten)

Course type Lecture
SWS 6
Frequency SoSe und WiSe
Workload attendance 84 h
Module label: System Integration of Renewable Energy

Module code: pre141

Credit points: 12.0 KP

Workload: 360 h

Applicability of the module:
- Sustainable Renewable Energy Technologies (Master) > Mastermodule

Responsible persons:
Lehnhoff, Sebastian (Module responsibility)

Prerequisites:

Skills to be acquired in this module:
- After successful completion of the module students should be able to:
  - explain the management, modelling and power balancing within future electricity grid configurations with high shares of fluctuating and distributed generation and the requirements for successful application to real power balancing regarding capacity utilization, robustness, and flexibility.
  - appraise the main components (incl. chemical storage options) involved in future AC-grid concepts, to soundly assess the reciprocal constrains between them to propose solutions for improving its performance.
  - explain necessary IT- and process control technology components, methods and processes to control and operate electrical energy systems.
  - estimate and evaluate the requirements and challenges of ICT and computer science which are caused by the development and integration of unforeseeable fluctuations of decentralised plants.
  - explain necessary conversion procedures and to judge the ecologic and economic balance.
  - categorise different grid-designs, including mini- and micro-grids.
  - compare different electricity markets existing currently (Futures Market, Day-Ahead-Market, Intraday-Market, Balancing Power Market, Self-Consumption) based on the motivation, role, advantages and limiting factors and to critically judge and assess the suitability of these concepts for promoting the implementation of higher shares of fluctuating distributed power generation within the electricity grid.
  - explain the technical principles and resulting limiting factors for different components required for power control within “Smart City”, “Smart Grid”, “Smart Home” concepts, estimate the influence of distributed control concepts and algorithms for decentralised plants and consumers in the so called Smart Grid energy systems and analyse their safety, reliability, real time capability and flexibility.

Module contents:
The module is designed to give specialized insight on the management, modelling and power balancing within future grid configurations. It gives the students a thorough overview on the challenges and solutions in electricity grids that shall accommodate a high share of fluctuating distributed generation. It deals with the technical and economic framework for a permissible electrical network as well as mathematical modelling and calculation methods to analyse conditions of electrical energy networks (in stationary conditions). Technology, economical energy industry and technical basic knowledge and methods are analysed by using concrete Smart Grid approaches. The basic calculation methods for an intelligent net management are introduced.

Future Power Supply Systems (Lecture & Seminar – 180 h workload):
- Technology and characteristics of conventional power plants based e.g. on coal, gas, and nuclear
- Fundamentals, structure, technologies and operation of (AC-) electricity grids (incl. balancing power, voltage management, etc.)
- Fluctuating distributed generation: Characteristics and solutions on the transmission and distribution grid levels, incl. storage, vehicle-to-grid-concepts, smart inverters, heat pumps / CHP, etc.
- Interactions between technology and economics: The different electricity markets (Futures Market, Day-Ahead-Market, Intraday-Market, Balancing Power Market, Self-Consumption) and their links to the physical world
  - “Smart City”, “Smart Grid”, “Smart Home”
  - Mini- and Micro-Grids
  - Energy scenarios and modelling
  - Chemical energy carriers in the energy system: power-to-gas (e.g. methane) and power-to-liquids (e.g. methanol)

Smart grid management (Lecture and Exercises – 180 h workload):
- Organisation of the EU energy market (regulatory framework, responsibility in liberalisation of electrical energy systems)
- Establishment and operation of electrical energy supply networks (network topology, statutory duties of supply, supply quality/system services, malfunctions and protection systems)
- Network calculation (complex pointer, effective/idle power, mathematical performance models/net model, transformation: node performance to node voltage and electricity, calculation of conductive current, power-flow calculation, fix-point-iteration, Newton-Raphson-Method, voltage drop, transformer...
Reader's advisory

Future Power Supply Systems:


Smart grid management:

- Konstantin, P.: „Praxisbuch Energiewirtschaft“, Springer 2006
- Lehnhoff, S.: „Dezentrales vernetztes Energiemanagement“, 2010

Links

Language of instruction English
Duration (semesters) 1 Semester
Module frequency once a year
Module capacity unlimited
Reference text Helpful previous knowledge:

- For the course “Smart grid management” is basic knowledge in Python Programming advisable.
- Basic knowledge on chemical processes (Chemistry-Primer: 1CP) and energy storage (course “Energy storage”) are also advantageous.
- Knowledge in Semiconductor Physics is desired (Semiconductor Physics Primer: 1CP)

Module level / module level MM (Mastermodul / Master module)
Modulart / type of module Wahlpflicht / Elective
Lehr-/Lernform / Teaching/Learning method Lectures, Exercises, Seminar

Vorkenntnisse / Previous knowledge

Examination Time of examination Type of examination
Final exam of module 2 Examinations Report (presentation: 50 min, paper: 5 pages) or Exercises (8 exercises): Future Power Supply, 50% weight. Oral Exam (ca. 30 minutes) or Exercises (8 exercises): Smart Grid Management, 50% weight

Course type Comment SWS Frequency Workload of compulsory attendance
Lecture 4 SoSe und WiSe 56
Seminar 4 SoSe und WiSe 56

Total time of attendance for the module 112 h
pre142 - Future Power Supply Systems

<table>
<thead>
<tr>
<th>Module label</th>
<th>Future Power Supply Systems</th>
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</thead>
<tbody>
<tr>
<td>Module code</td>
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<tr>
<td>Credit points</td>
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<td>Workload</td>
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</table>

**Applicability of the module**
- Sustainable Renewable Energy Technologies (Master) > Mastermodule

**Responsible persons**
- Agert, Carsten (Authorized examiners)
- Ravanbach, Babak (Authorized examiners)

**Prerequisites**

**Skills to be acquired in this module**

After successful completion of the module students should be able to:

- explain the management, modelling and power balancing within future electricity grid configurations with high shares of fluctuating and distributed generation and the requirements for successful application to real power balancing regarding capacity utilization, robustness, and flexibility.

- appraise the main components (incl. chemical storage options) involved in future AC-grid concepts, to soundly assess the reciprocal constrains between them to propose solutions for improving its performance.

- explain necessary conversion procedures and to judge the ecologic and economic balance

- categorise different grid-designs, including mini- and micro-grids

- compare different electricity markets existing currently (Futures Market, Day-Ahead-Market, Intraday-Market, Balancing Power Market, Self-Consumption) based on the motivation, role, advantages and limiting factors and to critically judge and assess the suitability of these concepts for promoting the implementation of higher shares of fluctuating distributed power generation within the electricity grid.

- explain the technical principles and resulting limiting factors for different components required for power control within “Smart City”, “Smart Grid”, “Smart Home” concepts, estimate the influence of distributed control concepts

**Module contents**

The module is designed to give specialized insight on the management, modelling and power balancing within future grid configurations. It gives the students a thorough overview on the challenges and solutions in electricity grids that shall accommodate a high share of fluctuating distributed generation. It deals with the technical and economic framework for a permissible electrical network as well as mathematical modelling and calculation methods to analyse conditions of electrical energy networks (in stationary conditions). Technology, economical energy industry and technical basic knowledge and methods are analysed by using concrete Smart Grid approaches. The basic calculation methods for an intelligent net management are introduced.

**Future Power Supply Systems (Lecture & Seminar – 180 h workload):**

- Technology and characteristics of conventional power plants based e. g. on coal, gas, and nuclear

- Fundamentals, structure, technologies and operation of (AC-) electricity grids (incl. balancing power, voltage management, etc.)

- Fluctuating distributed generation: Characteristics and solutions on the transmission and distribution grid levels, incl. storage, vehicle-to-grid-concepts, smart inverters, heat pumps / CHP, etc.

- Interactions between technology and economics: The different electricity markets (Futures Market, Day-Ahead-Market, Intraday-Market, Balancing Power Market, Self-Consumption) and their links to the physical world

- “Smart City”, “Smart Grid”, “Smart Home”

- Mini- and Micro-Grids

- Energy scenarios and modelling

- Chemical energy carriers in the energy system: power-to-gas (e.g. methane) and power-to-liquids (e.g. methanol)
<table>
<thead>
<tr>
<th>Reader's advisory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Links</td>
</tr>
<tr>
<td>Languages of instruction</td>
</tr>
<tr>
<td>Duration (semesters)</td>
</tr>
<tr>
<td>Module frequency</td>
</tr>
<tr>
<td>Module capacity</td>
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<tr>
<td>Modullevel / module level</td>
</tr>
<tr>
<td>Modulart / typ of module</td>
</tr>
<tr>
<td>Lehr-/Lernform / Teaching/Learning method</td>
</tr>
<tr>
<td>Examination</td>
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<tr>
<td>Seminar</td>
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### pre151 - Renewable Energy in Developing Countries

<table>
<thead>
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<tr>
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<td>Credit points</td>
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<tr>
<td>Responsible persons</td>
<td>Agert, Carsten (Authorized examiners)</td>
</tr>
<tr>
<td></td>
<td>Günther, Andreas (Authorized examiners)</td>
</tr>
<tr>
<td></td>
<td>Jimenez Martinez, Cuauhtemoc Adrian (Authorized examiners)</td>
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<tr>
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<td>Siebenhüner, Bernd (Authorized examiners)</td>
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<tr>
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<td>Torio, Herena (Authorized examiners)</td>
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</table>

#### Prerequisites

#### Skills to be acquired in this module

#### Module contents

#### Reader's advisory

#### Links

#### Languages of instruction
German, English

#### Duration (semesters)
1 Semester

#### Module frequency
unlimited

#### Module level / module level
BC (Basiscurriculum / Base curriculum)

#### Modulart / typ of module
Wahlpflicht / Elective

#### Vorkenntnisse / Previous knowledge

#### Examination

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<th>Type of examination</th>
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<td></td>
<td>1 Prüfungsleistung: Seminararbeit (40 S.) oder Referat (Präsentation - 45 Minuten, Ausarbeitung 20 Seiten) Im Seminar wird Aktive Teilnahme (siehe Ergänzung zu § 9 Abs. (6) ) gefordert.</td>
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</table>

#### Course type

<table>
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#### Total time of attendance for the module
112 h
pre034 - Renewable Energy Technologies II

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<td>Sustainable Renewable Energy Technologies (Master) &gt; Mastermodule</td>
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<td>Responsible persons</td>
<td>Agert, Carsten (Authorized examiners)</td>
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<td></td>
<td>Holtorf, Hans-Gerhard (Authorized examiners)</td>
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<td></td>
<td>Torio, Herena (Authorized examiners)</td>
</tr>
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<td>Wark, Michael (Authorized examiners)</td>
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<td>Pehiken, Alexandra (Authorized examiners)</td>
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</table>

Prerequisites

Skills to be acquired in this module

Module contents

Reader’s advisory

Links

Language of instruction | English

Duration (semesters) | 1 Semester

Module frequency

Module capacity | unlimited

Modullevel / module level | MM (Mastermodul / Master module)

Modulart / typ of module | Wahlpflicht / Elective

Vorkenntnisse / Previous knowledge

Examination

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Course type | Comment | SWS | Frequency | Workload of compulsory attendance |

- Lecture | 2 | SoSe oder WiSe | 28 |
- Seminar | 2 | SoSe oder WiSe | 28 |
- Exercises | 2 | SoSe oder WiSe | 28 |
- Practical training | 2 | SoSe oder WiSe | 28 |

Total time of attendance for the module | 112 h
**pre091 - Transferrable skills**

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**Responsible persons**

- Brudler, Evelyn (Authorized examiners)
- Holtorf, Hans-Gerhard (Authorized examiners)
- Aßmuth-Düster, Heidemarie (Authorized examiners)
- Kobusch, Ulrich (Authorized examiners)

**Prerequisites**

**Skills to be acquired in this module**

After successful completion of the module students should be able to:

- Identify and reflect their own interests and competences
- Discuss the topics of their interest/choice more profoundly
- Apply and transfer the acquired communication skills in various situations outside the classroom

**Module contents**

Within this module multiple courses with a highlight on communication are offered. From the offered courses students can select multiple courses with a combined workload of 180 hours to deepen their competence in these fields of interest. The following courses are currently eligible:

- Teaching in Renewable Energies
- Deutsch,
- Kreatives Schreiben (level B1+),
- Deutsch für Naturwissenschaftler (level B1+),
- Wissenschaftliches Arbeiten - Schwerpunkt Lesen und Schreiben (level B2+),
- Wissenschaftliches Arbeiten - Schwerpunkt Sprechen und Referieren (level B2+),
- Developing and Presenting a Conference Poster
- Academic Writing
- Module 1: Writing and Publishing a Research Paper
- Basics of Project Management

**Reader's advisory**

**Language of instruction**

English

**Duration (semesters)**

1 Semester

**Module frequency**

unlimited

**Module level / module level**

MM (Mastermodul / Master module)

**Modulart / typ of module**

Wahlpflicht / Elective

**Vorkenntnisse / Previous knowledge**
<table>
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<th>Type of examination</th>
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<td>Exercises</td>
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inf511 - Smart Grid Management

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<tr>
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<tr>
<td>Workload</td>
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Applicability of the module

- Master's Programme Business Informatics (Master) > Akzentsetzungsmodule der Informatik
- Master's Programme Computing Science (Master) > Angewandte Informatik
- Master's Programme Engineering Physics (Master) > Schwerpunkt: Renewable Energies
- Master's Programme Environmental Modelling (Master) > Mastermodule
- Sustainable Renewable Energy Technologies (Master) > Mastermodule

Responsible persons

Lehnhoff, Sebastian (Authorized examiners)

Lehrrenden, Die im Modul (Authorized examiners)

Prerequisites

Skills to be acquired in this module

After successful completion of the course the students should be able to understand the existing structures and technical basis of energy systems to produce, transfer and distribute electricity and their interaction and dependency on each other. They should have developed an understanding for necessary IT- and process control technology components, methods and processes to control and operate electrical energy systems. The students are able to estimate and evaluate the requirements and challenges of ICT and computer science which are caused by the development and integration of unforeseeable fluctuations of decentralised plants. The students will be able to estimate the influence of distributed control concepts and algorithms for decentralised plants and consumers in the so called Smart Grid energy systems. Regarding the requirements the students will be able to analyse the safety, reliability, realtime capability and flexibility of Smart Grid energy systems.

Professional competence

The students:

- understand the existing structures and the technical basis of energy systems producing, transferring and distributing electricity and their interaction and dependency on each other.
- develop an understanding for necessary IT- and process control technology components, methods and processes to control and operate electrical energy systems.
- estimate and evaluate the requirements and challenges of ICT and computer science which are caused by the development and integration of unforeseeable fluctuations of decentralised plants.
- estimate the influence of distributed control concepts and algorithms for decentralised plants and consumers in the so called Smart Grid energy systems.

Methodological competence

The students:

- analyse the safety, reliability, realtime capability and flexibility of Smart Grid energy systems
- use advanced mathematical methods to calculate networks

Social competence

The students:

- create solutions in small teams
- discuss their solutions

Self-competence

The students:

- reflect their own use of electricity as a limited resource

Module contents

Content of the Module: In this course information technology, economical energy industry and technical basic knowledge and methods are analysed by using concrete Smart Grid approaches. The basic calculation methods for an intelligent grid management are introduced.

This module deals with the technical and economical framework for a permissable electrical network as well as mathematical modelling and calculation methods to analyse conditions of electrical energy networks (in stationary conditions). These are:
The organisation of the EU energy market (regulatory framework, responsibility in liberalisation of electrical energy systems)
Establishment and operation of electrical energy supply networks (network topology, statutory duties of supply, supply quality/system services, malfunctions and protection systems)
Intelligent network management (Smart Grids), aggregation forms, machine learning approaches)

Suggested reading:
- Crastan V.: "Elektrische Energiesysteme II", Springer 2004

Links
Language of instruction  English
Duration (semesters)  1 Semester
Module frequency  jährlich
Module capacity  unlimited
Module level / module level  AS (Akzentsetzung / Accentuation)
Modulart / typ of module  je nach Studiengang Pflicht oder Wahlpflicht
Lehr-/Lernform / Teaching/Learning method  V+Ü
Vorkenntnisse / Previous knowledge

<table>
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<th>Examination</th>
<th>Time of examination</th>
<th>Type of examination</th>
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<td>Final exam of module</td>
<td>At the end of the semester</td>
<td>Oral exam</td>
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<table>
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<th>SWS</th>
<th>Frequency</th>
<th>Workload of compulsory attendance</th>
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<tr>
<td>Lecture</td>
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<td>Exercises</td>
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**Resilient Energy Systems**

<table>
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<tr>
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<tr>
<td>Module code</td>
<td>pre152</td>
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<tr>
<td>Credit points</td>
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<td>Applicability of the module</td>
<td>Sustainable Renewable Energy Technologies (Master) &gt; Mastermodule</td>
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**Responsible persons**

- Agert, Carsten (Authorized examiners)
- Jimenez Martinez, Cuauhtemoc Adrian (Authorized examiners)
- Torio, Herena (Authorized examiners)
- Agert, Carsten (Module responsibility)
- Torio, Herena (Module responsibility)

**Prerequisites**

**Skills to be acquired in this module**

After successful completion of the module students should be able to:

- analyze, and critically understand different definitions of resilience and fundamental concepts relevant in the context of energy systems analysis (e.g. complexity, homeostasis, equilibria, stressors,...)
- understand and interlink assessment methods, principles and theories for resilience analysis of energy supply systems in different scientific disciplines
- critically evaluate the suitability, meaningfulness and implications of different resilience-related indicators, theories and assessment methods from several disciplines
- develop a scientific discourse on suitable approaches for assessing particular aspects of a resilient energy system design in the context of a particular real-life case study
- identify main barriers, potentials and driving factors for improving one selected assessment approach in the context of its application to a case study
- perform a literature review, apply a selected resilience and extract the main related conclusions, arguing critically on them
- present scientific results and conclusions both verbally and in written form, including quotation to a professional standard

**Module contents**

The module “Resilient energy systems” provides the theoretical background for understanding main concepts and interdisciplinary scientific methods from the context of resilience assessment as well as their role in the debate towards resilient energy systems.

**Resilient Energy Systems (Lecture & Seminar, 180 h workload):**

- Definitions and fundamental concepts in resilience analysis of energy systems (complexity, homeostasis, equilibria, feedback loops,...)
- Approaches and methods for resilience assessment from different relevant disciplines:
  - epistemic approaches
  - resilience as guiding principle
  - aggregation methods for resilience assessment
  - cyber-security and informatics
  - environmental modelling
- risk and vulnerability analysis
- agent-based models
- governance studies

Reader's advisory


Links
Language of instruction English
Duration (semesters) 1 Semester

Module frequency

Module capacity unlimited

Modullevel / module level MM (Mastermodul / Master module)

Modulart / typ of module Pflicht / Mandatory

Lehr-/Lernform / Teaching/Learning method

Vorkenntnisse / Previous knowledge

Examination Time of examination Type of examination
Final exam of module At the end of the semester G

Course type Comment SWS Frequency Workload of compulsory attendance
Lecture 2 SoSe oder WiSe 28
Seminar 2 SoSe oder WiSe 28

Total time of attendance for the module 56 h
# Module: Mini-Grids

**Module label**: Mini-Grids  
**Module code**: pre153  
**Credit points**: 6.0 KP  
**Workload**: 180 h  
**Applicability of the module**: Sustainable Renewable Energy Technologies (Master) > Mastermodule  
**Responsible persons**  
**Prerequisites**  
**Skills to be acquired in this module**  
**Module contents**  
**Reader's advisory**  
**Links**  
**Languages of instruction**: German, English  
**Duration (semesters)**: 1 Semester  

## Module frequency

- **Module capacity**: unlimited  
- **Module level**: SPM (Schwerpunktmodul / Main emphasis)  
- **Module type**: Wahlpflicht / Elective  

## Teaching/Learning method

- **Vorkenntnisse / Previous knowledge**  

## Examination

- **Final exam of module**  
- **Time of examination**:  
- **Type of examination**: G  

### Course type

<table>
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<tr>
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</tr>
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<tbody>
<tr>
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## Total time of attendance for the module

- **Total time of attendance for the module**: 56 h
phy609 - Photovoltaic Physics

Module label Photovoltaic Physics
Module code phy609
Credit points 6.0 KP
Workload 180 h
  (Attendance: 56 hrs, Self study: 124 hrs)
Applicability of the module
  - Master's Programme Engineering Physics (Master) > Schwerpunkt: Renewable Energies
  - Sustainable Renewable Energy Technologies (Master) > Mastermodule
Responsible persons
  Kühn, Martin (Module responsibility)
  Gülay, Levent (Authorized examiners)
Prerequisites
  Solid-state-Physics, semi-conductor Physics, Module Renewable Energy Technologies I
Skills to be acquired in this module
  describe schematically the events around the pn-junction under bias in the dark and under illumination,
  calculate the width of the space charge region, use solar cell data sheets in their professional career, discuss
  the concepts of solar cell materials, design and optimization, choose a PV technology for a given project
Module contents
  This specialization module covers the physics of photovoltaics. The behaviour of solar cells is discussed from a
  fundamental physical point of view to explain the differences in performance and limits of various photovoltaic
  materials. Students learn how solar cells function, are designed and optimized, Optical and electronical
  properties of semiconductors, light absorption, Charge carrier generation/recombination/life time, Charge carrier
  transport across the pn-junction in equilibrium and under light and voltage bias, Transport equations, Current-
  voltage characteristics, efficiency, Quantum efficiency, Design concepts to
  optimize the efficiency, Overview of the most important PV technologies
Reader's advisory
  S. Hegedus, A. Luque, Handbook of Photovoltaic Science and Engineering, published John Wiley and Sons
  (2nd Edition 2011);
  Christiana Honsberg and Stuart Bowden, PVCDROM, http://www.pveducation.org/pvcdrom/instructions,
  Access date 2.10.2014;
  lecture notes for the respective courses
Links
Language of instruction English
Duration (semesters) 1 Semester
Module frequency Sommersemester
Module capacity unlimited
Modulelevel / module level MM (Mastermodul / Master module)
Modulart / typ of module Wahlpflicht / Elective
Lehr-/Lernform / Teaching/Learning method Vorlesung: 4 SWS, Übung: 2 SWS
Vorkenntnisse / Previous knowledge

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<th>SWS</th>
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<td>SoSe oder WiSe</td>
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<tr>
<td>Exercises</td>
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Total time of attendance for the module 56 h
# phy616 - Computational Fluid Dynamics 1 / 2

<table>
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<tr>
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<td>Attendance: 56 hrs, Self study: 124 hrs</td>
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<td>Master's Programme Engineering Physics (Master) &gt; European Wind Energy Master</td>
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<td>Sustainable Renewable Energy Technologies (Master) &gt; Mastermodule</td>
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<td>Responsible persons</td>
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<td>Lukassen, Laura (Authorized examiners)</td>
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<td>Stoevesandt, Bernhard (Authorized examiners)</td>
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<td>Lukassen, Laura (Module responsibility)</td>
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<td>Fluid Dynamics I</td>
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<tr>
<td>Skills to be acquired in this module</td>
<td>Deeper understanding of the fundamental equations of fluid dynamics. Overview of numerical methods for the solution of the fundamental equations of fluid dynamics. Confrontation with complex problems in fluid dynamics. To become acquainted with different, widely used CFD models that are used to study complex problems in fluid dynamics. Ability to apply these CFD models to certain defined problems and to critically evaluate the results of numerical models.</td>
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<tr>
<td>Module contents</td>
<td>CFD I:</td>
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<tr>
<td>The Navier-Stokes equations, filtering / averaging of Navier-Stokes equations, introduction to numerical methods, finite-differences, finite-volume methods, linear equation systems, NS-solvers, RANS, URANS, LES, DNS, turbulent flows, incompressible flows, compressible flows, efficiency and accuracy.</td>
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<td>CFD II:</td>
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<tr>
<td>Introduction to different CFD models, such as OpenFOAM and PALM. Application of these CFD models to defined problems from rotor aerodynamics and the atmospheric boundary layer.</td>
<td></td>
</tr>
<tr>
<td>J. Fröhlich, Large Eddy Simulationen turbulenter Strömungen, Teubner, Wiesbaden, 2006 (in German)</td>
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<td>• 1 Referat oder</td>
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<td>SoSe oder WiSe</td>
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phy641 - Energy Resources & Systems

Module label: Energy Resources & Systems

Module code: phy641

Credit points: 6.0 KP

Workload: 180 h
- Attendance: 56 hrs, Self-study: 124 hrs

Applicability of the module:
- Master's Programme Engineering Physics (Master) > Schwerpunkt: Renewable Energies
- Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
- Sustainable Renewable Energy Technologies (Master) > Mastermodule

Responsible persons:
- Knipper, Martin (Authorized examiners)
- Torio, Herena (Authorized examiners)
- Knipper, Martin (Module responsibility)
- Agert, Carsten (Module responsibility)

Prerequisites:
- After successful completion of the module students should be able to:
  - characterize the global energy system and analyze the structure and constraints of today's energy system,
  - explain the availability and connection between solar and wind energy,
  - identify the problems and challenges of energy supply due to fluctuating energy resources with varying and seasonal load profiles,
  - relate the solar irradiance conversion process as well as the atmospheric radiation balance of the earth to Wind Energy Meteorology.

Skills to be acquired in this module:

Module contents:
This module will give an overview on the global energy system and the challenges of energy supply due to fluctuating energy resources with varying and seasonal load profiles.

Energy Meteorology (Lecture - 90 h workload)

Section I: Solar Irradiance
- Radiation laws,
- Solar geometry,
- Interaction of solar irradiance with the atmosphere,
- Radiation climatology,
- Solar radiation model,
- Statistical properties of solar irradiance,
- Measuring devices to ascertain solar radiation balance,
- Satellite-supported data acquisition to assess solar irradiance,

Section II: Wind Flow
- Origin and potential of atmospheric energy movements, Heat balance of the atmosphere,
- Physical laws of atmospheric flow,
- Wind circulation in the atmosphere, local winds,
- Wind flow in atmospheric layers (vertical structure, Ekman Layer),
- Assessment of wind potential (European Wind Atlas: model, concept,
- Wind Measurements,

Energy Systems (Lecture - 90 h workload)
- Definitions, separation electrical - thermal energy use,
- Resources and reserves,
- Energy system analysis: Efficiencies at various levels of the energy chain; Exergy analysis,
- Energy scenarios,
- Climate change,
- Advanced (power plant) technologies for conventional fuels,
- Electric power systems with large shares of renewables

Reader's advisory:
- Energy Meteorology:
  - IEA Word Energy Outlook (http://worldenergyoutlook.org/)
Energy Systems:
- Boyle, G. et al. (Eds.): Energy Systems and Sustainability (Oxford University Press, 2003)
- Blok, K.: Introduction to Energy Analysis (Techne Press, Amsterdam, 2007)
- EIA: International Energy Outlook 2016 (www.eia.doe.gov/forecasts/ieo/)

Links

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<th>Language of instruction</th>
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Examination

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Course type

- Lecture

SWS

- 4

Frequency

- SoSe oder WiSe

Workload attendance

- 56 h
phy647 - Future Power Supply Systems

Module label  Future Power Supply Systems
Module code       phy647
Credit points  6.0 KP
Workload  180 h
Attendance: 56 hrs, Self study: 124 hrs

Applicability of the module
- Master's Programme Engineering Physics (Master) > Schwerpunkt: Renewable Energies
- Sustainable Renewable Energy Technologies (Master) > Mastermodule

Responsible persons
Agert, Carsten (Authorized examiners)

Prerequisites
Knowledge from module RE technology I, Mathematics

Skills to be acquired in this module
After successful completion of the module students should be able to
- explain the management, power balancing and the provision of ancillary services within future electricity grid configurations with high shares of fluctuating and distributed generation
- perform power system simulation with related software tools
- describe different grid-designs, including mini- and microgrids
- compare different markets for electricity (Futures' Market, Day-Ahead-Market, Intraday-Market, Balancing Power Market, Self-Consumption) and assess the suitability of these concepts for promoting the implementation of higher shares of fluctuating distributed power generation within the electricity grid.
- explain the technical principles and resulting limiting factors of concepts and components required for power control within 'Smart City', 'Smart Grid', and 'Smart Home' concepts

Module contents
Future Power Supply Systems:
- Technology and characteristics of conventional power plants based e.g. on coal, gas, and nuclear,
- Fundamentals, structure, technologies and operation of (AC-) electricity grids (incl. balancing power, voltage management, etc.),
- Fluctuating distributed generation: Characteristics and solutions on the transmission and distribution grid levels, incl. storage, vehicle-to-grid-concepts, smart inverters, heat pumps / CHP, etc,
- Interactions between technology and economics: The different electricity markets (Futures Market, Day-Ahead-Market, Intraday-Market, Balancing Power Market, Self-Consumption) and their links to the physical world, - 'Smart City', 'Smart Grid', 'Smart Home', - Mini- and Micro-Grids,
- Energy scenarios and modelling,
- Chemical energy carriers in the energy system: power-togas (e.g. methane) and power-to-liquids (e.g. methanol)

Reader's advisory

Links
Language of instruction  English
Duration (semesters)  1 Semester
Module frequency  Sommersemester
Module capacity  unlimited
Modullevel / module level  MM (Mastermodul / Master module)
Modulart / typ of module  Wahlpflicht / Elective
Lehr-/Lernform / Teaching/Learning method  Lecture and Seminar: 4 hrs/week

Vorkenntnisse / Previous knowledge
Examination  Time of examination  Type of examination
Final exam of module  Report (presentation: 50 min, Term-paper: 5 pp.) or Exercises (8 Exercises). In addition, active participation is required. The criteria to fulfill the requirement of the active participation are
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## phy648 - Wind Resources and its Applications

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<td>Workload</td>
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<td>Attendance: 72 hrs, Self study: 108 hrs</td>
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<td>Sustainable Renewable Energy Technologies (Master) &gt; Mastermodule</td>
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<tr>
<td>Heinemann, Detlev (Authorized examiners)</td>
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<td>Waldl, Hans-Peter (Authorized examiners)</td>
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<td>Kühn, Martin (Module responsibility)</td>
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<tr>
<td>assess different aspects of wind energy farms by modelling, comparison, explanation of wind energy potential, wind energy farm's output, power curves, wind energy project development, assess in detail in uences of meteorological/ climatological aspects on the performance of wind power systems, summarize physical processes governing atmospheric wind flows, value atmospheric boundary layer flow relevant for wind power conversion, argue methods for wind resource assessment and forecasting</td>
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<td>Advanced Wind Energy Meteorology (Lecture -90 h workload)</td>
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<td>Atmospheric Boundary Layer (turbulence, vertical structure, special BL effects)</td>
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<td>Atmospheric Flow Modelling: Linear models, RANS and LES models</td>
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<td>Wind farm modelling</td>
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<td>Offshore-Specific Conditions</td>
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<td>Resource Assessment and Wind Power Forecasting</td>
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<td>Wind Measurements and Statistics</td>
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<td>Wind Energy Applications - from Wind Resource to Wind Farm Operations (Lecture - 90 h workload)</td>
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<td>Evaluation of Wind Resources</td>
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<td>Weibull Distribution</td>
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<td>Wind velocity measurements to determine energy yield</td>
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<td>Basics of Wind Atlas Analysis and Application Program (WAsP) Method, Partial models using WAsP</td>
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<tr>
<td>Measure-Correlate-Predict (MCP) Method of long term corrections of wind measurement data in correlation to long term reference data</td>
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<td>Conditions for stable, neutral and instable atmospheric conditions</td>
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<td>Wind yield from wind distribution and the power curve Basics in appraising the yearly wind yield from a wind turbine.</td>
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<td>Wake Effect and Wind Farm</td>
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<td>Recovery of original wind fields in the downstream of wind turbines</td>
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<td>Basics of Riso Models</td>
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<td>Spacing and efficiency in wind farms</td>
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<td>Positive and Negative Effects of Wind Farms</td>
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<td>Wind Farm Business</td>
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<td>Income from the energy yield from wind farms</td>
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<td>Profit optimization by increase of energy production</td>
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<td>Wind farm project development</td>
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<td>Wind farm operation and Surveillance of power production vs. wind climate, power curves, and turbine availability</td>
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<td>Reader's advisory</td>
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phy649 - Design of Wind Energy Systems

Module label: Design of Wind Energy Systems
Module code: phy649
Credit points: 6.0 KP
Workload: 180 h
- Attendance: 72 hrs, Self study: 108 hrs

Applicability of the module:
- Master's Programme Engineering Physics (Master) > Schwerpunkt: Renewable Energies
- Sustainable Renewable Energy Technologies (Master) > Mastermodule

Responsible persons:
- Kühn, Martin (Authorized examiners)
- Kühn, Martin (Module responsibility)

Prerequisites:
Basics in Wind Energy Utilisation

Skills to be acquired in this module:
Design of Wind Energy Systems:
The students attending the course will have the possibility to expand and sharpen their knowledge about wind turbine design from the basic courses. The lectures include topics covering the whole spectrum from early design phase to the operation of a wind turbine. Students will learn in exercises how to calculate and evaluate design aspects of wind energy converters.
At the end of the lecture, they should be able to:
- estimate the site specific energy yield,
- calculate the aerodynamics of wind turbines using the blade element momentum theory,
- model wind fields to obtain specific design situations for wind turbines,
- estimate the influence of dynamics of a wind turbine, especially in the context of fatigue loads,
- transfer their knowledge to more complex topics such as simulation and measurements of dynamic loads,
- calculate the economic aspects of wind turbine

Aerelastic Simulation of Wind turbines:
- student who has met the objectives of the course will be able to:
  - understand the basic concept of an aero-servo-elastic computer code to determine the unsteady aerodynamic loads, derive and validate the required parameters to model the aero-hydro-elastic response of a wind turbine, identify and interpret the required empirical parameters to correct the blade element momentum (BEM) method with respect to dynamic in flow, unsteady airfoil aerodynamics (dynamic stall), yawed flow, dynamic wake modeling, explain the effects of the different models on the resulting time series and validate the code, interpret design standards for on- and offshore wind turbines, select the required load cases according to sitespecific environmental data, identify the dimensioning load cases and calculate design loads for different main components of a wind turbine.

Module contents:
Design of Wind Energy Systems
- Introduction to industrial wind turbine design, rotor aerodynamics and Blade Element Momentum (BEM) theory,
- dynamic loading and system dynamics, wind field modelling for fatigue and extreme event loading, design loads and design aspects of onshore wind turbines, simulation and measurements of dynamic loads, design of offshore wind turbines, power quality and grid integration on wind turbines.

Aeroelastic Simulation of Wind turbines:
The course focuses on the practical implications and hands-on experience of the aero-hydro-servo-elastic modelling and simulation of wind turbines. The subjects are similar but the treatment is complementary to the parallel course 'Design of Wind Energy Systems', which deals with the underlying theoretical background:
- advanced wind field modelling for fatigue and extreme event loading, modelling of wind farm flow and wake effects, rotor aerodynamics (e.g. stationary or dynamic effects, comparison of Blade Element Momentum theory and more advanced methods like free vortex methods or CFD), structural dynamics and dynamic modelling of wind turbine structures (modelling by ordinary or partial differential equations, stochastics, multi body system modelling), advanced control of wind turbines, design standards, design loads and design aspects of off-shore and onshore wind turbines.
The students analyse in pairs a model of an entire wind turbine with the aid of a typical wind turbine design tool like GH Bladed, Flex5 or Aerodyn/FAST.

Reader's advisory:
Garrad Hassan, Bladed. Wind Turbine Design Software, Theory Manual; Selected papers from e.g. Wind Energy Journal, Wiley Interscience

Links

Language of instruction: English
Duration (semesters): 1 Semester
Module frequency: Wintersemester
Module capacity: unlimited
Modulelevel / module level: MM (Mastermodul / Master module)
Modulart / typ of module: Wahlpflicht / Elective
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**phy987 - Control of Wind Turbines and Wind Farms**

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<th>Control of Wind Turbines and Wind Farms</th>
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<td>Credit points</td>
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| Applicability of the module | • Master's Programme Engineering Physics (Master) > Schwerpunkt: Renewable Energies  
• Sustainable Renewable Energy Technologies (Master) > Mastermodule |
| Responsible persons | Kühn, Martin (Authorized examiners)  
Petrovic, Vlaho (Authorized examiners)  
Kühn, Martin (Module responsibility) |

**Prerequisites**

**Skills to be acquired in this module**

After successful completion of the course, students

- will have understood the structure and the main components of the control system in a wind farm
- will have understood the main objectives for a wind farm control system and will be able to develop appropriate control algorithms for the said objectives
- will have understood relevant physical phenomena in a wind farm
- will be able to develop a control-oriented model of a wind turbine, and will have understood how to use it for the design and analysis of control algorithms
- will be able to independently apply different techniques from control engineering
- will have trained how to use methods from linear algebra and mathematical analysis for the design and analysis of control algorithms

**Module contents**

The course covers the main techniques used in wind turbine and wind farm control. The course is structured in five sections:

**Section I: Introduction to control in wind energy**

- Introduction to the governing physics
- Control objectives in wind energy
- Overview of the control system

**Section II: Control oriented modelling**

- Modelling in time domain
- Modelling in frequency domain
- Time and frequency response

**Section III: Standard wind turbine control**

- Torque and pitch control
- Tuning of a PI controller
- Stability analysis
- Control of coupled systems

**Section IV: Advanced wind turbine control**

...
• Advanced control design approaches
• State space control
• Estimation techniques

Section V: Wind farm control
• Wake control strategies
• Active power control
• Power maximization

Reader's advisory


Links

Language of instruction  English
Duration (semesters)  1 Semester
Module frequency  jährlich
Module capacity  unlimited
Modullevel / module level  EB (Ergänzungsbereich / Complementary)
Modulart / typ of module  Wahlpflicht / Elective
Lehr-/Lernform / Teaching/Learning method  Vorlesung: 4 SWS, Übung: 2 SWS

Vorkenntnisse / Previous knowledge
Basic knowledge in linear algebra and mathematical analysis is required. Furthermore, a basic understanding of wind turbines and wind farms is required (e.g. Design of Wind Energy Systems). A good grasp of the Matlab/Simulink environment is required for exercises.

Examination

Final exam of module  Time of examination  Type of examination

KL
Course type  Comment  SWS  Frequency  Workload of compulsory attendance
Lecture  2  SoSe oder WiSe  28
Exercises  2  SoSe oder WiSe  28

Total time of attendance for the module  56 h
Pre014 - Fundamentals for Renewable Energy

Module label: Fundamentals for Renewable Energy
Module code: pre014
Credit points: 6.0 KP
Workload: 180 h

Applicability of the module:
- Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
- Sustainable Renewable Energy Technologies (Master) > Mastermodule

Responsible persons:
- Hoppmann, Jörn (Authorized examiners)
- Knecht, Robin (Authorized examiners)
- Torio, Herena (Authorized examiners)
- Ziethe, Paul (Authorized examiners)

Prerequisites:

Skills to be acquired in this module:

After successful completion of the module students should be able to:
- identify their competence and incompetence with respect to the study of renewable energies
- describe basic knowledge from a wide field of disciplines as required for renewable energies
- understand the most important economic principles
- have a basic understanding of the functioning of energy markets
- have an overview of the types and effectiveness of policies to promote renewable energy technologies
- understand the interaction between society and renewable energy technologies
- know which aspects play an important role when founding renewable energy start-ups and developing corporate strategies in the renewable energy sector
- be able to assess alternative investment and financing possibilities in the context of renewable energy
- understand how renewable energy innovation projects can be structured and implemented

Module contents:

The module is designed to give students a solid foundation to successfully start the MSc programme. The content from the field of Physics, Mathematics as well as Electrical and Mechanical Engineering aims to provide a homogenous foundation for the study of renewable energies. The introduction to fundamental knowledge from the field of energy economics and management complements the homogenized technical knowledge.

The following Primers are offered:
- Mathematics
- Programming
- Modelling
- Electronic Power Systems
- Semiconductor Physics
- Material Characterization
- Thermodynamics
- Fluid Dynamics

The course "Renewable Energy Management" offers an introduction to the most important areas relevant to the management of renewable energy companies. To this end, the course first provides a general introduction to economic fundamentals and principles. Students then gain insights into the following topics:
- Energy markets
- Renewable energy policy and climate policy
- Energy and society
- Foundation and strategies of renewable energy companies
• Investment and financing in the renewable energy sector
• Innovation management in the renewable energy sector

Each of these topics will be explored in depth through practical exercises, including guest lectures, simulations, stakeholder discussions, case studies and investment calculations.

**Reader's advisory**

Primer: lecture notes for the respective courses

**RE Management (optional):**


**Links**

<table>
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**Vorkenntnisse / Previous knowledge**

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**Total time of attendance for the module**

84 h
pre017 - Physical Principles of Renewable Energy Converters

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<tr>
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Applicability of the module
- Master’s Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
- Sustainable Renewable Energy Technologies (Master) > Mastermodule

Responsible persons
- Torio, Herena (Authorized examiners)
- Holtorf, Hans-Gerhard (Authorized examiners)
- Jimenez Martinez, Cuauhtemoc Adrian (Authorized examiners)
- Knipper, Martin (Authorized examiners)
- Günther, Andreas (Authorized examiners)
- Agert, Carsten (Module responsibility)
- Knipper, Martin (Module responsibility)

Prerequisites

Skills to be acquired in this module

After successful completion of the module students should be able to:

- perform laboratory measurements in a university environment according to scientific standards
- present a sound analysis of the results and related conclusions in a scientific report
- analyse and interpret measurement results using relevant and widely used software tools
- work and communicate their results with international and interdisciplinary partners

Module contents

Laboratories (Theoretical/practical Seminar ? 120 h workload)

- Introductory Laboratory
- Interaction Light and Matter
- Heat Transfer
- Fluid Dynamics
- Storage Technologies
- Scientific Writing

Reader's advisory
Lecture notes for the respective courses
<table>
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pre022 - Solar Energy

Module label | Solar Energy
---|---
Module code | pre022
Credit points | 6.0 KP
Workload | 180 h

Applicability of the module
- Master's Programme Engineering Physics (Master) > Schwerpunkt: Renewable Energies
- Sustainable Renewable Energy Technologies (Master) > Mastermodule

Responsible persons
- Torio, Herena (Authorized examiners)
- Knipper, Martin (Authorized examiners)
- Torio, Herena (Module responsibility)
- Agert, Carsten (Module responsibility)

Prerequisites

Skills to be acquired in this module

After successful completion of the module students should be able to:

- understand, describe and compare major technologies for solar energy use: solar thermal and photovoltaic systems
- analyse various system components and their interconnections within a solar energy system.
- critically appraise and assess various technologies for solar energy use and components involved in such solar systems.
- size and evaluate the performance of solar systems as a function of their operation conditions, components and system layout
- critically evaluate non-technical impact and side effects when implementing renewable energy supply systems

Module contents

This module gives an overview on solar thermal and photovoltaic technologies. Main focus hereby are the scientific principles of components and their technical description as well as first suitable system performance assessment methods.

Photovoltaics (Lecture: 90 h workload)

Physics of PV:

- Basic and most important properties of solar radiation related to photovoltaics
- PV cells basics: Fundamental physical processes in photovoltaic materials
- Characterization and basic modelling of solar cells
- Component Description: PV generator; Charge controller; Inverter; Balance of system components; System Description
- Grid Connected System
- Stand Alone System

Solar Thermal Energy (Seminar & Exercises: 90 h workload)

- Assessment of solar thermal ambient parameters: regional global, diffuse, reflected solar radiation on horizontal and on tilted plane, ambient temperature
- Solar thermal system components: collectors; heat exchangers; thermal storage; thermally driven compression chillers
- Solar cooling systems and components
- Characterization of solar thermal systems, their operation and performance
- F-Chart and Utilizability methods as main methods for assessing system performance

Reader's advisory

Solar Energy PV

- Stuart R. Wenham, Martin A. Green, Muriel E. Watt & Richard Corkish (Edit.), 2007: Applied Photovoltaics, Earthscan Publications Ltd.

Links

Languages of instruction

Duration (semesters) 1 Semester

Module frequency

Module capacity unlimited

Modullevel / module level MM (Mastermodul / Master module)

Modulart / typ of module Pflicht / Mandatory

Vorkenntnisse / Previous knowledge

Examination Time of examination Type of examination
Final exam of module At the end of the lecture period; submission of the report at the end of the semester 2 Examinations: Written Exam (1.5h, weight 50%) and Presentation of a Paper (15 min presentation, 5 pages report, weight 50%)

Course type Comment SWS Frequency Workload of compulsory attendance
Lecture 2 SoSe oder WiSe 28
Exercises 2 SoSe oder WiSe 28

Total time of attendance for the module 56 h
pre025 - Wind Energy and Storage

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Applicability of the module

- Sustainable Renewable Energy Technologies (Master) > Mastermodule

Responsible persons

- Hölling, Michael (Authorized examiners)
- Holtorf, Hans-Gerhard (Authorized examiners)
- Agert, Carsten (Module responsibility)
- Holtorf, Hans-Gerhard (Module responsibility)

Prerequisites

Skills to be acquired in this module

After successful completion of the module students should be able to:

- Critically evaluate and describe basic characteristics and functioning of wind energy converters
- Understand the physical principal of wind energy conversion
- Understand wind turbine aerodynamics
- Critically evaluate and describe electrochemical storage systems with a focus on batteries as well as hydrogen storage systems (electrolyser, gas storage and fuel cells)

Module contents

Basics of Wind Energy:

- Wind characterization and anemometers
- Aerodynamic aspects of wind energy conversion
- Wind turbine performance
- Design of wind turbines
- Dimensional analysis and pi-theorem

Energy Storage:

- Fundamentals of electrochemistry and thermodynamics
- Energy and environmental balances
- Basics of hydrogen production (materials, processes, efficiencies, environmental impacts)
- Basics of fuel cells (function, materials, construction, systems applications)
- Basics of hydrogen storage systems (their setup, control, safety aspects)
- Fundamental setup of most common battery types
- Fundamental chemical reactions in these batteries
- Operational characteristics of batteries (charging & discharging, weir processes and service lives).

### Reader's advisory

- Hoppecke, Installation, commissioning and operating instructions for vented stationary lead-acid batteries, Hoppecke, Editor. 2013, Hoppecke Batterien GmbH & Co. KG: Brilon, Germany.

### Links

**Language of instruction**  
English

**Duration (semesters)**  
1 Semester

**Module frequency**  
Annual, Winter Semester, first semester in SuRE and EMRE

**Module capacity**  
unlimited

**Modullevel / module level**  
MM (Mastermodul / Master module)

**Modulart / typ of module**  
Pflicht / Mandatory

### Lehr-/Lernform / Teaching/Learning method

**Vorkenntnisse / Previous knowledge**

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<td>Written Exam (wind energy) &amp; Active Participation (energy storage)</td>
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### Course type

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**Total time of attendance for the module**  
56 h
### pre042 - Water and Biomass Energy

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**Applicability of the module**
- Master's Programme Engineering Physics (Master) > Schwerpunkt: Renewable Energies
- Sustainable Renewable Energy Technologies (Master) > Mastermodule

**Responsible persons**
- Wark, Michael (Authorized examiners)
- Holtorf, Hans-Gerhard (Authorized examiners)
- Pehiken, Alexandra (Authorized examiners)
- Wark, Michael (Module responsibility)
- Holtorf, Hans-Gerhard (Module responsibility)

**Prerequisites**

**Skills to be acquired in this module**

After the completion of the module students should be able to

- critically evaluate and compare two Renewable Energy conversion processes which allow continuous power supply on demand (hydropower and biomass energy)
- confront those systems to a Renewable Energy conversion process with intermittent output (marine power)
- discuss extreme situations in Renewable Energy systems' source and transfer such situations to other Renewable Energy systems
- analyse various system components and their interconnections within a complex Renewable Energy supply system,
- evaluate the Renewable Energy supply systems' operational size and efficiency,
- critically evaluate non-technical impact and side effects when implementing renewable energy supply systems
- understand the basic chemical background of bioenergy-related materials, systems and processes

**Module contents**

**Biomass Energy (Lecture - 90 h workload)**

- Energy mix overview; gas, heat, electricity, Pros and Cons, of biomass,
- Chemical composition of biomass: sugar, cellulose, starch, fats, oils, proteins, lignin,
- Natural photosynthesis in plants: chemical storage of solar energy; general mechanisms,
- Chemistry and Biology (microorganism) of Biogas Technology,
- Conversion processes of biomass: classification, main pathways,
- Introduction to catalysis used in biomass conversion,
- Chemical fuels (chemical energy storage) from biomass,
- Routes to platform chemicals and separation processes,
Technology concepts for bioenergy usage,

Introduction into economical and legal constraints.

Hydro and Marine Power (Lecture + Excursion - 90 h workload)

- Revision of hydraulic basics and their application to hydro and marine power.
- Hydropower and marine power resources and their representation
- Technological and economical state of the art.
- Description of such systems' components, their characteristics, their interaction in a system, their main features and their challenges

Reader's advisory

Biomass Energy

- Fagerström, A., Al Seadi, T., Rasi, S., Briseid, T. (2018). The role of Anaerobic Digestion and Biogas in the Circular Economy. Murphy, J.D. (Ed.) IEA Bioenergy Task 37, 2018: 8
- Cushion, Elizabeth, Adrian Whiteman, and Gerhard Dieterle. Bioenergy development: issues and impacts for poverty and natural resource management
- Schlögl, Robert (2013). Chemical energy storage (Elektronische Ressource ed.). Berlin [u.a.]: De Gruyter.

Hydro and Marine Power


Links
Language of instruction English
Duration (semesters) 1 Semester
Module frequency Wintersemester
Module capacity unlimited

Reference text
Within the lecture Hydro and Marine Power an excursion to a hydropower plant and the catchment area will be offered. The duration of this excursion will be in total 5 hours.

It is recommended to know the basics of photosynthesis.

Modullevel / module level MM (Mastermodul / Master module)
Modulart / typ of module Pflicht / Mandatory

Vorkenntnisse / Previous knowledge Basics of
- Hydrodynamics
- Mechanical Engineering
- Electrical Engineering
- Recommended: Basic knowledge of General Chemistry

Examination

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Total time of attendance for the module 56 h
**pre064 - Renewable Energy Complementary Topics and Transferable Skills**

**Module label** | Renewable Energy Complementary Topics and Transferable Skills
---|---
**Module code** | pre064
**Credit points** | 6.0 KP
**Workload** | 180 h

**Applicability of the module**
- Sustainable Renewable Energy Technologies (Master) > Mastermodule

**Responsible persons**
- Holtorf, Hans-Gerhard (Authorized examiners)
- Agert, Carsten (Module responsibility)
- Holtorf, Hans-Gerhard (Module responsibility)

**Prerequisites**

**Skills to be acquired in this module**

After completing the module students will be able to:

- describe basic knowledge in two of a wide field of disciplines (technical, scientific, social, political, transferrable, language) as required for the implementation of renewable energy
- critically discuss basic principles of the implementation of renewable energy
- justify their personal decision on educational fields for their career development

**Module contents**

The module is designed to give students an outlook on fields which have not been covered so far in their previous lectures and specialization modules.

The content from different disciplines allows deepening knowledge and skills in the fields of technology, natural and social sciences, policy-making, transferrable and personal development skills, and languages. It intends to allow students tailoring their personal education for their professional careers.

A selection of examples of courses eligible in this module are:

All SuRE specialization lectures (beyond the own specialisation lectures), Ecological Economics, International Environmental Governance or any university language courses.

**Reader's advisory**

Refer to selected lectures within pre064

**Languages of instruction**
- German, English

**Duration (semesters)**
- 1 Semester

**Module frequency**
- unlimited

**Module level / module level**
- MM (Mastermodul / Master module)

**Modulart / typ of module**
- Wahlpflicht / Elective

**Lehr-/Lernform / Teaching/Learning method**
- Refer to specific lecture

**Vorkenntnisse / Previous knowledge**
- Refer to specific lecture

**Examination**
- Time of examination
- Type of examination

**Final exam of module**
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**Total time of attendance for the module** 84 h
pre113 - Photovoltaic Systems

Module label: Photovoltaic Systems
Module code: pre113
Credit points: 6.0 KP
Workload: 180 h (180 Stunden)

Applicability of the module:
- Master's Programme Engineering Physics (Master) > Schwerpunkt: Renewable Energies
- Sustainable Renewable Energy Technologies (Master) > Mastermodule

Responsible persons:
- Holtorf, Hans-Gerhard (Authorized examiners)
- Knipper, Martin (Authorized examiners)
- Torio, Herena (Module responsibility)
- Holtorf, Hans-Gerhard (Module responsibility)

Prerequisites

Skills to be acquired in this module:

After successful completion of the module students should be able to:

- categorize and feature different PV systems
  - PV on-grid,
  - PV off-grid / stand alone,
  - PV-pumping,
  - PV-hybrid
  by their setup and by standard quality indicators.

- explain the operation principles of the listed PV systems
- explain concepts behind PV system design
- design a photovoltaic system by Fermi Estimate
- design a photovoltaic system by a simulation software
- be aware of the limitation of both design methods
- discuss energy flow diagrams of PV systems
- describe in depth involved balance of system components e.g.
  - inverter,
  - charge controllers
  - cabling
  - generator stand
  - storage battery with a focus on housing (ventilation)

Module contents:

This specialization module covers more in-depth topics concerning photovoltaics systems.

The module consists of:
Photovoltaic Systems Lecture (90h workload)

Description and operation of PV System's balance of system components

- inverter,
- charge controllers
- cabling
- generator stand
- storage battery with a focus on housing (ventilation)

Quality indicators for PV Systems and their regional differences

- PV on-grid,
- PV off-grid / stand alone,
- PV-pumping,
- PV-hybrid

Sizing of PV systems – back of the envelope approach as well as by a simulation software

Photovoltaic Systems Seminar (90h workload)

Within the seminar groups of up to five students select a PV system related research question, work on the solution and present their findings.

In addition, external PV experts are invited to present from their work experience.

An excursion to a PV power plant concludes the lessons learned in the field.

Reader's advisory

- Konrad Mertens, Photovoltaik, Lehrbuch zu Grudlagen, Technologie und Praxis, 5. Aktualisierte Auflage
- GSES, Off-Grid PV Systems – Design and Installation, first edition international, April 2020
- Lecture notes for the respective courses

Links

Languages of Instruction  German, English
Duration (semesters)  1 Semester
Module frequency  unlimited
Module capacity  unlimited
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<td>Lecture, Exercise, Seminar &amp; Excursion</td>
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Active Participation and Seminar Presentation
Lecture, Exercise, Seminar & Excursion

<table>
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Total time of attendance for the module 56 h
**pre114 - Solar Energy Meteorology**

<table>
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**Workload**

- 180 h 
  
- 180 Stunden 

**Applicability of the module**

- Master's Programme Engineering Physics (Master) > Schwerpunkt: Renewable Energies
- Sustainable Renewable Energy Technologies (Master) > Mastermodule

**Responsible persons**

- Torio, Herena (Module responsibility)
- Holtorf, Hans-Gerhard (Module responsibility)
- Schmidt, Thomas (Authorized examiners)

**Prerequisites**

Successful participation in "Energy Meteorology 5.06.M117"

**Skills to be acquired in this module**

After successful completion of the module students should be able to

- explain the concepts of physical processes governing the surface solar irradiance available for solar energy applications
- model the solar radiation and show their expertise in application, adaptation and development of models
- discuss state-of-the-art-methods in satellite-based irradiance estimation and solar power forecasting
- discuss and present state of the art of the application of modern solar energy meteorology on a wide range (from residential systems to solar power plants, from solar thermal to photovoltaic systems)

**Module contents**

This specialization module covers more in-depth topics concerning solar energy meteorology.

Based on students' knowledge about the solar resource, solar thermal and photovoltaic technology, students deepen their knowledge on the resource for such systems.


- Physics of radiative processes in the atmosphere
- Physical modelling of atmospheric radiative transfer (incl. computing tools)
- Solar irradiance modelling for solar energy applications
- Solar spectral irradiance: Theory and relevance for solar energy systems
- Satellite-based estimation of solar irradiance
- Solar irradiance (and solar power) forecasting
- Solar radiation measurements: Basics and setup of high quality measurement system

**II. Solar Energy Meteorology Applications (Lecture and Seminar – 90h workload)**
sources of solar data and discussion of their quality
solar resource assessment:
  - basic models,
  - measurements,
  - satellite models
  - data sets
validation and application of solar resource data sets
forecasting of solar radiation: sky-camera forecasts, satellite-based forecasts, numerical weather predictions, statistical methods
  - forecast validation
  - selected applications
irradiance and PV power forecasting
application of solar resource data for yield assessment

Reader's advisory
  - https://wui.cmsaf.eu/safira/action/viewDoiDetails?acronym=SARAH_V001
  - https://nsrdb.nrel.gov/
  - re.jrc.ec.europa.eu/pvgis/

Links
Language of instruction English
Duration (semesters) 1 Semester
Module frequency Annual, summer semester
Module capacity unlimited
Module level / module level MM (Mastermodul / Master module)
Modulart / typ of module Wahlpflicht / Elective
Lehr-/Lernform / Teaching/Learning method Presence (when possible)
Vorkenntnisse / Previous knowledge Physical principles of Black Body Radiation
    Basics of Solar Radiation
Examination Time of examination Type of examination
Final exam of module During the semester 1 x active participation 1 x written exam
Course type Comment SWS Frequency Workload of compulsory attendance
Lecture 2 SoSe oder WiSe 28
Seminar 2 SoSe oder WiSe 28
Total time of attendance for the module 56 h
**pre017 - Physical Principles of Renewable Energy Converters**

<table>
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**Applicability of the module**  
- Sustainable Renewable Energy Technologies (Master) > Mastermodule

**Responsible persons**

**Prerequisites**

**Skills to be acquired in this module**

**Module contents**

**Reader's advisory**

**Links**

**Languages of instruction**  
German, English

**Duration (semesters)**  
1 Semester

**Module frequency**  
unlimited

**Modullevel / module level**  
MM (Mastermodul / Master module)

**Modular / typ of module**  
Pflicht / Mandatory

**Lehr-/Lernform / Teaching/Learning method**

**Vorkenntnisse / Previous knowledge**

**Examination**

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**Course type**

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**Total time of attendance for the module**  
70 h
**pre019 - Fundamentals of Renewable Energy**

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pre062 - Renewable Energy Complementary Topics and Transferable Skills

Module label
Renewable Energy Complementary Topics and Transferable Skills

Module code
pre062

Credit points
6.0 KP

Workload
180 h
180 Stunden

Applicability of the module
- Sustainable Renewable Energy Technologies (Master) > Mastermodule

Responsible persons
Holtorf, Hans-Gerhard (Module responsibility)
Agert, Carsten (Module responsibility)
Holtorf, Hans-Gerhard (Authorized examiners)

Prerequisites

Skills to be acquired in this module

After completing the module students will be able to:

- describe basic knowledge in two of a wide field of disciplines (technical, scientific, social, political, transferrable, language) as required for the implementation of renewable energy
- critically discuss basic principles of the implementation of renewable energy
- justify their personal decision on educational fields for their career development

Module contents

The module is designed to give students an outlook on fields which have not been covered so far in their previous lectures and specialization modules.

The content from different disciplines allows deepening knowledge and skills in the fields of technology, natural and social sciences, policy-making, transferrable and personal development skills, and languages. It intends to allow students tailoring their personal education for their professional careers.

A selection of examples of courses eligible in this module are:

All SuRE specialization lectures (beyond the own specialisation lectures), Ecological Economics, International Environmental Governance or any university language courses.

Reader's advisory
Refer to selected lectures within pre064

Links

Language of instruction
English

Duration (semesters)
1 Semester

Module frequency
Typically second SuRE semester (summer semester)

Module capacity
unlimited

Reference text

In case you are uncertain whether a lecture is accountable for this module please contact the module responsible.

However, mind:

All SuRE specialization lectures (beyond the own specialisation lectures), Ecological Economics, International Environmental Governance or any university language courses are creditable lectures within pre064.
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Abschlussmodul

**mam - Master´s Thesis Module**

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**Responsible persons**

- Agert, Carsten (Authorized examiners)
- Heinemann, Detlev (Authorized examiners)
- Günther, Andreas (Authorized examiners)
- Gütay, Levent (Authorized examiners)
- Hammer, Annette (Authorized examiners)
- Knecht, Robin (Authorized examiners)
- Jimenez Martinez, Cuauhtemoc Adrian (Authorized examiners)
- Hölling, Michael (Authorized examiners)
- Holtorf, Hans-Gerhard (Authorized examiners)
- Kraft, Martin (Authorized examiners)
- Kühn, Martin (Authorized examiners)
- von Bremen, Lüder (Authorized examiners)
- Lukassen, Laura (Authorized examiners)
- Siebenhüner, Bernd (Authorized examiners)
- Schmidt, Andreas Hermann (Authorized examiners)
- Schneemann, Jörge (Authorized examiners)
- Steinfeld, Gerald (Authorized examiners)
- Stoevesandt, Bernhard (Authorized examiners)
- Torio, Herena (Authorized examiners)
- Wark, Michael (Authorized examiners)
- Pehlken, Alexandra (Authorized examiners)
- Lehnhoff, Sebastian (Authorized examiners)
- Scheele, Ulrich (Authorized examiners)
- Sievers-Glotzbach, Stefanie (Authorized examiners)
- Ravanbach, Babak (Authorized examiners)
- Malz, Simone (Authorized examiners)
- Steinberger-Wickens, Robert (Authorized examiners)
- Waldl, Hans-Peter (Authorized examiners)

**Prerequisites**

**Skills to be acquired in this module**

The master thesis module finalizes and concludes the master programme. The student presents the achieved results as a written thesis and defends the results / conclusions to a board of examiners.
As a general objective for the Master Thesis, the student shall demonstrate the ability to constructively, critically and independently formulate, discuss and communicate issues at stake, integrating theory and methodology related to Renewable Energy.

As specific competency objectives within the Master Thesis, after completion the student shall be able to:

- demonstrate knowledge of relevant and latest publications concerning the selected topic
- elaborate the Master Thesis on the basis of clearly formulated, general objectives and specific characteristics of the topic
- identify and put to use in an operational manner empirical or other scientific material and methods that are appropriate in relation to the subject
- develop a balanced discussion of material, methods, results and possible consequences of these in relation to the field of Renewable Energy
- present the Master Thesis orally and defend the results and conclusions in a critical discussion

The module is designed to apply and deepen the methodologies acquainted throughout the PPRE programme to a specific scientific problem given by the supervisor. In order to achieve a result the student needs to apply scientific as well as key-competencies described in the next section.

Students have understood the scientific problem, they have learned the ropes of the problem, they have selected, acquainted or deepened a set of scientific and methodologies and key-competencies necessary to solve the problem and they have applied those methods.

The publication of thesis results is appreciated.

Module contents

The Master Thesis finalises the course of studies within PPRE.

Master Thesis Colloquium (Colloquium 180 h workload)

- Skills for thesis elaboration
- negotiation of conditions & rules with the supervisors
- setting the scene
- scientific writing,
- literature research & management (database),
- time management,
- communication with involved stakeholders,
- networking with helpful partners,
- development of research question
- Presentation and discussion of thesis project proposal (own and other students' project proposals)

Finalizing discussion with network (PPRE colleagues, friends and supervisors)

Reader's advisory

Links

Languages of instruction

Duration (semesters) 1 Semester

Module frequency

Module capacity unlimited

Modullevel / module level ---

Modulart / typ of module je nach Studiengang Pflicht oder Wahlpflicht

Lehr-/Lernform / Teaching/Learning method
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