Module Handbook Oldenburg

Fakultät 5: Mathematik und Naturwissenschaften Institut für Physik *Subject:* European Master in Renewable Energy Winter Term 2016/2017	*Category:* Master Module *Degree award:* Master
Emphases: -	*Sections:* -
Module reference number/Title: **pre311 - Renewable Energy Basics**	
Duration: 1 semester *Cycle:* once a year *Type of module:* mandatory *Level:* MM (master module) *This module should be taken in* 1st semester	*Type of program:* - Lecture, Seminar, Exercise, Laboratory *Language:* English *Attainable credit points:* 6,00 CP *Workload:* 180 hours *Required attendance:* -
Person responsible for the programme: Prof. Dr. Carsten Agert	*Person responsible for this module:* Prof. Dr. Joachim Peinke
Alternative person(s) responsible for this module: Tanja Behrendt, Robin Knecht, Hans-Gerhard Holtorf, Jörg Ohland, Paul Ziethe	*Examiner(s):* All listed persons

Objective of the module / skills:

After completing the module, the student will

- have a good understanding of the physical principles of Renewable Energy Technologies
- be able to apply principal mathematics related with the underlying physical laws and rules to measure and solve problems during their further studies
- have a good understanding of the fundamentals of electrical circuits and related physical laws
- have a good understanding of the fundamentals of electrical machines and the interaction of electrical components of the electric grid
- have a good understanding of the basic concepts of the photovoltaic effect in semi-conductors
- be familiar with the measurement procedures needed for the winter lab experiments in the subject related modules.
- be familiar with working and studying in intercultural teams
- be familiar with the experimental set-ups of the PPRE lab
- understand to relate physical, engineering, and mathematical laws to models of energy supply technologies.
- be able to establish simple models and measurement strategies to investigate the behaviour of the

respective models.
- be familiar with the principles of scientific working

Content of the module:

Renewable Energy Basics
- Thermodynamics
- Hydrodynamics
- Black and Grey Body Radiation
- Property of (humid) air
- Heat Transfer
- Economic Evaluation of Investments

Winter Introductory Laboratory
- Simple electrical circuits
- Inner resistance of power sources
- Measurement of time depending signals
- Measurement of temperature and radiation
- Introduction of standard sensors in radiation and temperature measurement
- Introduction of measurement devices: multimeter, oscilloscope, x-t-writer

Electrical Power Systems
- Fundamentals in AC/DC
- Fundamentals of magnetic fields
- Transformers
- DC machines
- Asynchronous-machines
- Synchronous machines

Semi-Conductor Physics
- Definition of semi-conductor
- Crystal Lattice
- Atom models
- Chemical bonding
- Quantum mechanics
- Photoelectric effect
- pn-Junction
- Solar cell

Suggested reading:

Borgnakke, Claus, Sonntag, Richard E. Fundamentals of Thermodynamics, ISBN 978-0470041925.

Grote, Karl-Heinrich, Fedhusen, Jörg, Dubbel, Taschenbuch für den Maschinenbau, ISBN 978-3-642-17305-9, Springer Verlag

Kittel, Charles, 1986: Introduction to Solid State Physics; John Wiley & Sons.

Labuhn, Dirk, Rombert, Oliver, Keine Panik vor Thermodynamik, ISBN 978-3-8348-0180-7, Vieweg,

Merz, Hermann, 2002: Electric machines and drives, fundamentals and calculation examples for beginners; VDE-Verlag.

Mukund Patel, 1999: Wind and Solar Power Systms, CRC Press, London

Nahvi, Mahmood & Edminister, Joseph, 2003: Schaum's Outline of Electric Circuits; 4th ed., McGraw-Hill.

Oelert, Gerhard, Economic issues of renewable energy systems : a guide to project planning; ISBN, Roßdorf TZ Verlag

Sørensen, Bent, 2003: Renewable energy. Its physics, engineering, use, environmental impacts, economy and planning aspects; 2nd ed., Acad.Press.

Taylor, John Robert, 1997: An introduction to error analysis -- the study of uncertainties in physical measurements; Univ. Science Books; Sausalito, Califiifornia; 2. ed..

Twidell, John & Weir, Tony, 2006: Renewable Energy Resources; reprint of 1st ed., Taylor& Francis.

General books on experimental laboratory work and report writing:

Kirkup, Les, 1994: Experimental methods -- an introduction to the analysis and presentation of data; Brisbane, Wiley.

Kulschewski, Udo, Knecht , Robin and colleagues, update 2013: Reader for the Introductory Lab Course: AC/DC principles, fast signals, power, measurement strategies, sensors in RE and measurement devices

Comments:

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Weblink:

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Prerequisites for admission:

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Helpful previous knowledge:

Basic mathematics, basic physics, basic engineering (mechanical, electrical & electronic)

Associated with the module(s):

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Maximum number of students / selection criteria:

-

Types of examinations:

RE Basics Physics (25%): Oral exercise (1 hour)

Semiconductor Physics (25%): Written exam (0.5 hours)

Electrical Power Systems (25%): Written exam (0.5 hours)

Solar Spectrum Lab (25%): Written report (10 - 20 pages)

Examination periods:

RE Basics Physics: After end of lectures (end of October)

Semiconductor Physics: After end of lectures (mid-December)

Electrical Power Systems: After end of lectures (mid-January)

Solar Spectrum Lab: During Semester

Registration procedure:

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Fakultät 5: Mathematik und Naturwissenschaften Institut für Physik *Subject:* European Master in Renewable Energy Winter Term 2016/2017	*Category:* - Master Module *Degree award:* - Master
Emphases: -	*Sections:* -

Module reference number/Title:

pre312 - Wind Energy

Duration: 1 semester *Cycle:* once a year *Type of module:* mandatory *Level:* MM (master module) *This module should be taken in* 1st semester	*Type of program:* - Lecture, Tutorial, Laboratory, Excursion *Language:* English *Attainable credit points:* 5,00 CP *Workload:* 150 hours *Required attendance:* -
Person responsible for the programme: Prof. Dr. Carsten Agert	*Person responsible for this module:* Dr. Michael Hölling
Alternative person(s) responsible for this module: Robin Knecht	*Examiner(s):* All listed persons

Objective of the module / skills:

After completing the module, the student will

- have a good understand of the basics of wind energy converters (WECs) including the forces acting on the turbine blades and how they are related to the blade design, the maximum power extractable from the wind and the principle of wind turbine control strategies.
- be able to characterise wind turbines with common non-dimensional parameters like power coefficient and tip speed ratio.
- have a critical understand of varying wind conditions at different sites and their consequences for wind turbines design
- understand the measurement principles on drag and lift forces
- be able to establish power-and cp/lambda curves.
- be able to set up the experimental procedure for measuring the targeted parameters, collect data in a scientific format and analyse and critical review retrieved data

Content of the module:

Lecture:

- Wind speed measurements
- Wind field characterization
- Wind power and Betz limit
- Wind turbines - general design
- Wind and rotor blade interaction
- Power losses

- Control strategies
- Power curves

Lab work: The energy conversion process in wind turbines tested within a small wind tunnel.

- Drag and lift force, stall effect
- Blade forms
- Evaluation of lift and drag coefficients
- Cp/Lambda curve
- Tip-speed ratio

Suggested reading:

Burton, T., Sharpe, D., Jenkins, N. & Bossanyi, E., 2001: Wind Energy Handbook, John Wiley

Gasch, Robert & Twele, Jochen, 2004: Wind Power Plants: Fundamentals, Design, Construction and Operation; Earthscan Publications Ltd.

Kulschewski, Udo & Knecht , Robin et al., update 2013: Reader for the Winter Laboratory Course: Physical Principals of Renewable Energy Converters

Comments:

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Weblink:

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Prerequisites for admission:

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Helpful previous knowledge:

Basics Fluid Dynamics: pressure, kinetic energy, boundary layer effects, flow structures, Lift and drag force,

Basic Mathematics: Vectors, differential equations, integral equations, basic statistics

Associated with the module(s):

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Maximum number of students / selection criteria:

-

Types of examinations:

Written exam (75%): 1.5 hours

Written laboratory report (25%): 10 - 20 pages

Examination periods:

Written exam: At the end of lecture period (end of January)

Written laboratory report: During Semester

Registration procedure:

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Fakultät 5: Mathematik und Naturwissenschaften Institut für Physik *Subject:* European Master in Renewable Energy Winter Term 2016/2017	*Category:* Master Module *Degree award:* Master
Emphases: -	*Sections:* -

Module reference number/Title:

pre313 - Solar Energy

Duration: 1 semester *Cycle:* once a year *Type of module:* mandatory *Level:* MM (master module) *This module should be taken in* 1st semester	*Type of program:* - Lecture, Laboratory *Language:* English *Attainable credit points:* 5,00 CP *Workload:* 150 hours *Required attendance:* -
Person responsible for the programme: Prof. Dr. Carsten Agert	*Person responsible for this module:* Prof. Dr. Jürgen Parisi
Alternative person(s) responsible for this module: Hans-Gerhard Holtorf, Robin Knecht	*Examiner(s):* All listed persons

Objective of the module / skills:

After completing the module students will
- critically understand the characteristics of components of solar thermal and photovoltaic systems
- critically understand the architecture and characteristics of solar thermal and photovoltaic systems
- be able to critically perform the energy balances of systems
- have a good understanding of sensor systems for controlling and monitoring of thermal and electric solar systems and their components
- be able to scientifically describe solar systems (operation, efficiency, performance parameters)
- be able to compare solar thermal systems to solar electric systems in terms of energy output and dependencies on meteorological input
- be able to compare solar systems to other renewable energy systems in terms of energy and dependencies on meteorological input.
- have a good understanding of the characteristics of solar and solar thermal collectors
- be able to establish measurement procedures in order to analyse characteristics of the given setups
- be able to apply standard physical and mathematical formulas to evaluate the experimental setups
- be able to analyse and critical review the retrieved data from experiments

Content of the module:

Solar system's components in stationary and dynamic operation:
- their functioning,
- the different technologies,
- the state of the art

- their characteristics and working points

Photovoltaics (PV):
- PV-cells
- charge controller
- inverter
- storage (batteries)
- further components (cabling, generator stand, electric protection)

Solar thermal:
- collectors (flat plate, vacuum tube, concentrating systems)
- thermal storage
- miscellaneous components (circulation pumps, piping, heat insulation)

Photovoltaic Systems:
- PV stand alone systems
- PV grid connected systems
- photovoltaic pumping systems
- hybrid systems

Solar Thermal Systems:
- domestic hot water supply
- heating supporting systems
- concentrating solar thermal systems.

Lab Work:
- PV cell characteristics
- solar collector characteristics

Suggested reading:

Duffie, John A. & Beckman, William A., 2006: Solar Engineering of Thermal Processes, Wiley.

Green, Martin A., 1981: Solar cells : operating principles, technology and system applications, Prentice Hall.

Green, M.A., 2007: Third Generation Photovoltaics, Advanced Solar Energy Conversion, Springer Series in Photonics

Heimrath, R., 2004: Simulation, Optimierung und Vergleich solarthermischer Anlagen zur Raumwärmeversorgung für Mehrfamilienhäuser, PhD Thesis, TU Graz.

Henning, H.M. 2003: Solar assisted air conditioning of buildings - A handbook for planners.

International Organization for Standardization, 1994: Test methods for solar collectors, IEA, Geneva

Markvart, Tom and Castaner, Luis, 2003: Practical Handbook of Photovoltaics, Fundamentals and Applications, Elsevier Science

McQuiston, Faye, Parker, Jerald & Spitler, Jeffrey, 2005: Heating, Ventilation and Air Conditioning, Wiley

Nelson, Jenny, 2003: The Physics of Solar Cells (Properties of Semiconductor Materials), Imperial College Press.

Peuser, Felix A., Remmers, Karl-Heinz & Schnauss, Martin, 2002: Solar Thermal Systems, Successful Planning and Construction, Earthscan

Publications Ltd.

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

Twidell, John & Weir, Toni, 2005: Renewable Energy Resources Taylor & Francis.

Weiss, Werner, 2004: Solar Heating Systems for Houses: A Design Handbook for Solar Combisystems, IEA

Kulschewski, Udo & Knecht , Robin et al., update 2013: Reader for the Winter Laboratory Course: Physical Principals of Renewable Energy Converters

Comments:

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Weblink:

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Prerequisites for admission:

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Helpful previous knowledge:

Fundamentals of

- Black & Grey Body Radiation
- Heat Transfer
- Semiconductor Physics
- Thermodynamics
- Electrical Engineering
- Electronic Engineering

Associated with the module(s):

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Maximum number of students / selection criteria:

-

Types of examinations:

Solar Energy Systems (60%): Oral exercise (1 hour)

PV Cell Laboratory (20%): Written report (10 - 20 pages)

Solar Collector Laboratory (20%): Written report (10 - 20 pages)

Examination periods:

Solar Energy Systems: At the end of the lecture period (end of January)

PV Cell Laboratory: During Semester

Solar Collector Laboratory: During Semester

Registration procedure:

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Fakultät 5: Mathematik und Naturwissenschaften Institut für Physik *Subject:* European Master in Renewable Energy Winter Term 2016/2017	*Category:* Master Module *Degree award:* Master
Emphases: -	*Sections:* -

Module reference number/Title:

pre314 - Energy Meteorology & Storage Technologies

Duration: 1 semester *Cycle:* once a year *Type of module:* mandatory *Level:* MM (master module) *This module should be taken in* 1st semester	*Type of program:* - Lecture, Laboratory *Language:* English *Attainable credit points:* 7,00 CP *Workload:* 210 hours *Required attendance:* -
Person responsible for the programme: Prof. Dr. Carsten Agert	*Person responsible for this module:* Dr. Detlev Heinemann
Alternative person(s) responsible for this module: Carsten Agert, Robin Knecht, Robert Steinberger-Wilckens	*Examiner(s):* All listed persons

Objective of the module / skills:

After completing this module, students will
- have a critical understanding of the conditions concerning the availability of solar radiation
- have a good understanding of fundamental atmospheric processes
- understand the close interaction of radiation with the atmosphere and the constraints on wind flows relevant for wind power generation
- will be able to apply basic radiation laws and to practically perform simple wind power assessments
- have a good understanding of various concepts of electrical storage systems and state of the art technical developments
- be able to critically understand the efficiency of conversion steps in storing and activation of energy
- have an overview of the electrochemical, thermodynamic, engineering, and materials science basics of Fuel Cell and Hydrogen technologies, their development status, and their applications areas
- have learned about the sensitivity of sensors
- have understood the performance of a battery/load system and are able to perform state of charge measurements to express the performance of a battery

Content of the module:

Solar Energy Meteorology:
- Radiation laws
- Solar geometry
- Interaction of solar radiation with the atmosphere

- Climatology of solar radiation
- Solar radiation modelling and measurements

Wind Energy Meteorology:
- Origin of atmospheric air flow, energy balance of the atmosphere
- Basic physics of atmospheric motion
- Wind climatology: Atmospheric circulation, local wind systems
- Wind in the atmospheric boundary layer (characteristics, vertical profile)
- Wind energy resource assessment and measurements

Electrical Energy Storage Technologies:
- Primary and secondary batteries
- redoxflow batteries
- super-capacitors

Non-electrical storage concepts:
- fly wheels
- adiabatic-compressed air storage
- superconductors
- pumped storage systems

„Bridging technologies“ to heat storage:
- Heat pumps and Combined heat and power systems (CHP's)

Fuel Cells and Hydrogen:
- Introduction and technology overview
- Hydrogen generation, handling and storage
- hydrogen applications and markets
- Low Temperature Fuel Cells
- High Temperature Fuel Cells
- Fuel Cells Market Introduction

Lab Work:
- Solar Spectrum
- Lead-Acid Battery

Suggested reading:

Baxter, Richard, 2005 : Energy Storage: A Nontechnical Guide, PennWell Corp

Bockris/Reddy, 1998: Modern Electrochemistry, Plenum Press, New York/London.

Emeis, Stefan, 2013: Wind Energy Meteorology – Atmospheric Physics for Wind Power Generation, Springer.

Fisch, N., et al.,2005: Wärmespeicher, Bine Informationsdienst, Solarpraxis, Berlin.

U.S. Department of Energy, Office of Fossil Energy, National Energy Technology Laboratory, 2004: Fuel Cell Handbook (Seventh Edition); by EG&G Technical Services, Inc.; http://www.netl.doe.gov/File%20Library/research/coal/energy%20systems/fuel%20cells/FCHandbook7.pdf; last access: May 2014

Hoogers, Gregor, 2002: Fuel Cell Technology Handbook (Mechanical Engineering Series, CRC, 1 edition.

IEA: World Energy Outlook, release 2013 (http://www.worldenergyoutlook.org/), last access: May 2014

Iqbal, M., 1984: An Introduction to Solar Radiation. Academic Press, Toronto

Larminie,James & Dicks, Andrew, 2003: Fuel Cell Systems Explained, Wiley, 2nd edition.

Linden, D. & Reddy, T.B., 2002: Handbook of Batteries. Third Edition, McGraw-Hill, New York.

Liou, K.-N.: An Introduction to Atmospheric Radiation, 2002: Academic Press; 2 edition.

Myers, Daryl M., 2013: Solar Radiation – Practical Modeling for Renewable Energy Applications, CRC Press.

Comments:

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Weblink:

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Prerequisites for admission:

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Helpful previous knowledge:

Basic knowledge in mathematics & physics

Associated with the module(s):

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Maximum number of students / selection criteria:

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Types of examinations:

Energy Meteorology (35%): Written exam (1.5 hours)

Energy Storage (35%): Written exam (1.5 hours)

Hydrogen & Fuel Cells (15%): Written exam (0.5 hours)

Battery Lab (15%): Written report (10 - 20 pages)

Examination periods:

Energy Meteorology: At the end of lecture period (end of January)

Energy Storage: At the end of lecture period (end of January)

Hydrogen & Fuel Cells: After end of lectures (mid-January)

Battery Lab: During Semester

Registration procedure:

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Fakultät 5: Mathematik und Naturwissenschaften Institut für Physik *Subject:* European Master in Renewable Energy Winter Term 2016/2017	*Category:* Master Module *Degree award:* Master
Emphases: -	*Sections:* -

Module reference number/Title:

pre315 - Energy Systems & Society

Duration: 1 semester *Cycle:* once a year *Type of module:* mandatory *Level:* MM (master module) *This module should be taken in* 1st semester	*Type of program:* - Lecture, Seminar *Language:* English *Attainable credit points:* 4,00 CP *Workload:* 120 hours *Required attendance:* -
Person responsible for the programme: Prof. Dr. Carsten Agert	*Person responsible for this module:* Dr. Detlev Heinemann
Alternative person(s) responsible for this module: Michael Golba, Simone Malz	*Examiner(s):* All listed persons

Objective of the module / skills:

After the completion of this module the students will

- have a critical understanding of political decision making processes, lobby groups and administrative hurdles in realisation of energy policy
- have a good understanding of factors other than technical influencing future energy scenarios depending on regional and national conditions
- have a good understanding of the structure of the global energy system
- be able to critically interpret energy statistics and to identify different stages of energy conversion
- be familiar with all available energy resources and their future role in the global energy system
- be familiar with the instrument of energy scenarios and able to interpret their results
- be able to critically follow scientific discussions in the physical background and impacts of global climate change
- understand basic economic concepts
- understand the organization of a market economy
- know the relevance of competition and monopoly
- understand the role of regulation for energy markets
- be able to undertake a desk-top research on a complex topic
- be able to give a presentation on an individual country (or region), focusing on renewable energy
- know about several other countries' and regions' situation
- to perform team research
- be able to present in front of an audience and to moderate a discussion

Content of the module:

Energy Systems
- basic terminology on energy units
- definition and discussion of various forms of energy
- overview of energy resources and reserves
- the global energy situation (energy consumption, energy balances, noncommercial uses of energy)
- energy scenarios (methodologies, main results for possible energy futures)
- techno-economic methods and aspects of energy use (energy and exergy analyses, life cycle analysis, external costs, etc.
- human-made greenhouse effect

Energy Economics
- the ten principles of economics
- the role of costs for decision making
- markets, competition, monopoly
- regulation and environmental policy
- investment decision, finance and risk management

Country Report
- analysis and presentation of an individual country or region
- geographic, climatic, historic, economic and political situation
- focus on (renewable) energy matters
- team research and presentation, followed by a discussion (moderated by team)

Suggested reading:

Blok, Kornelis, 2007: Introduction to Energy Analysis, Techne Press, Amsterdam

Boyle, Godfrey, Everett, Bob & Ramage, Janet, 2004: Energy Systems and Sustainability, Oxford University Press.

Chartcenko, Nikolaj Vasil'evic, 1998: Advanced Energy Systems, Taylor & Francis, London.

GEA, 2012: Global Energy Assessment – Toward a Sustainable Future, Cambridge University Press and International Institute for Applied System Analysis, Laxenburg.

Nakicenovic, Nebojsa, 1998: Global Energy Perspectives, International Institute for Applied Systems Analysis, Cambridge University Press.

Pfaffenberger, Wolfgang: Energy Economics - An Introduction, 126 pages and further literature given in this book. Lecture Script.

Ramage, Janet, 1997: Energy: A Guidebook, Oxford University Press.

Statistical Review of World Energy 2013, 2013: British Petroleum;
http://www.bp.com/en/global/corporate/about-bp/energyeconomics/

statistical-review-of-world-energy-2013.html , last access: June 2014

World Energy Assessment Overview: 2004 Update: Energy and the Challenge of Sustainability; UNDP (Ed.): http://www.undp.org/content/dam/aplaws/publication/en/publications/environment-energy/www-ee-library/sustainable-energy/world-energyassessment-overview-2004-update/World%20Energy%20Assessment%20Overview-2004%20Update.pdf , last access: June 2014

Country Reports from previous years

Comments:	*Helpful previous knowledge:*
-	-

Weblink: - *Prerequisites for admission:* -	*Associated with the module(s):* -

Maximum number of students / selection criteria:

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Types of examinations:

Energy Systems (40%): Written exam (1.5 hours)

Energy Economics (25%): Written exam (0.5 hours)

Country report (35%): Written report 15 – 20 pages & Presentation (20 min plus 10 min discussion)

Examination periods:

Energy Systems: At the end of lecture period (end of January)

Energy Economics: After end of lectures (mid-December)

Country report: During Semester

Registration procedure:

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Fakultät 5: Mathematik und Naturwissenschaften Institut für Physik *Subject:* European Master in Renewable Energy Winter Term 2016/2017	*Category:* Master Module *Degree award:* Master
Emphases: -	*Sections:* -

Module reference number/Title:

pre316 - Biomass Energy & Hydro Energy

Duration: 1 semester *Cycle:* once a year *Type of module:* mandatory *Level:* MM (master module) *This module should be taken in* 1st semester	*Type of program:* - Lecture, Excursion *Language:* English *Attainable credit points:* 3,00 CP *Workload:* 90 hours *Required attendance:* -
Person responsible for the programme: Prof. Dr. Carsten Agert	*Person responsible for this module:* Dr. Alexandra Pehlken
Alternative person(s) responsible for this module: Hans-Gerhard Holtorf, Robin Knecht	*Examiner(s):* All listed persons

Objective of the module / skills:

After the completion of this module the student will
- have a good understanding the potential of Biomass as an energy carrier
- be able to critically assess the sustainability of biomass, and hence the advantages and limits of biomass to energy
- have a good understanding of the main technical components of micro hydro power, tidal power, and wave power systems
- be able to size a Micro-hydro Power Plant for a given local geographic and hydrological conditions
- be able to critically assess advantages and disadvantages of micro hydro power, tidal and wave power systems in comparison with other renewable energy technology from a technical point of view

Content of the module:

Biomass Energy:
- introduction into Photosynthesis, chemical storage of solar energy, efficiency of various
- composition of biomass: sugar, starch, protein, fats, lignin
- typical soil conditions and the relation to plant growth, energy content of different plants
- typical energy plants in various regions and climates
- biomass usage in various geographical and climate regions
- traditional and modern technologies of energy biomass usage and its efficiency
- degradation processes of biomass: micro-organisms, classification and metabolism

Hydro Energy:

- theoretical background (general hydraulic terms, Bernoulli equation, major empirical formulae)
- water resource (catchment area, seasonal precipitation, flow duration curve, dam and run off river)
- marine resource (tides and waves, time dependency, energy & power content)
- powerhouse (penstock, water hammer, cavitation, tailrace)
- turbines (main types of turbines, their characteristics & their components)
- generators (main types of generators & their characteristics)
- control System (adaptation power input and load)

Lab Work:

- acceptance test of a centrifugal pump

Suggested reading:

Biomass

Bagain, Sundar & Shakya Idira, 2005: A successful Model of Public Private Partnership for Rural Household Energy Supply,

Bhojvaid, P.: Biofuels towards a greener and secure energy supply, Rajkamal electric Press, Delhi.

Biomass Energy Data Book of the US Department of Energy for Download: http://cta.ornl.gov/bedb/download.shtml; last access 5/2014

Devi, Lopamudra, 2005: Catalytic Removal of biomass tars, Selbstverlag, Eindhoven

FAO: http://www.fao.org/home/en/, last access 5/2014

Karki, Amrit, Shrestra, Jagan Nath & Bagain, Sundar, 2005: Biogas, BSPNepal.

Klass, Donald L., 1998: Biomass for Renewable Energy, Fuels, and Chemicals, Academic Press.

National Renewable Energy Lab: http://www.nrel.gov/learning/re_biomass.html; last access 5/2014

Rahman, Tazmilur, 2006: Green energy development model in the St. Martins Island and energy from coconut palm biomass, Dhaka/Nowroze Kitabistan.

Stassen, Hubert, Quaak Peter & Knoef,Harrie, 1999: Energy from Biomass: A Review of Combustion and Gasification Technologies (World Bank Technical Paper),World Bank Publications.

van der Burgt, Maarten & Higman Chistopher, 2008 : Gasification, Gulf Professional Publishing; 2nd edition.

Hydro Energy

Davis, Scott & Laschuk, Corrie, 2003: Microhydro, Clean Power from Water, New Society Publishers.

Harvey, Adam & Brown, Andy, 1998: Micro-Hydro Design Manual: A Guide to Small-Scale Water Power Schemes, Practical Action.

Inversin, Allen, 1990: Micro-Hydropower Sourcebook, NRECA international Foundation, Washington.

Ludwig,Art , 2005: Water Storage: Tanks, Cisterns, Aquifers, and Ponds for Domestic Supply, Fire and Emergency Use, Oasis Design.

Smith, Nigel, 2008: Motors as Generators for Micro-Hydro Power, Practical Action; 2nd edition.

Thake, Jeremy, 2000: The micro-hydro Pelton turbine manual: design, manufacture and installation for small-scale hydro-power, ITDG Publ., London.

Hardisty, Jack, 2009: The Analysis of Tidal Stream Power, Wiley, ISBN: 978-0- 470-72451-4

Roebuck, Kevin, Wave Power, 2011: High Impact Strategies, What You Need to Know: Definitions, Adoptions, Impact, Benefits, Maturity, Vendors, Tebbo, ISBN 1743332521

Comments: - *Weblink:* - *Prerequisites for admission:* -	*Helpful previous knowledge:* - Basic knowledge on chemical and biological conversion processes - Photosynthesis - Principles of degradation of biomass (aerobic/anaerobic) - Basic fluid dynamics - Basic mechanical engineering *Associated with the module(s):* -
Maximum number of students / selection criteria: - *Types of examinations:* Hydro Power (30%): Written exam (1 hour) Biomass (40%): Written exam (1 hour) Pump Lab (30%): Written report (10 - 20 pages) *Examination periods:* Hydro Power: At the end of lecture period (end of January) Biomass: At the end of lecture period (end of January) Pump Lab: During Semester *Registration procedure:* -	