Modulhandbuch

European Master in Renewable Energy - Master's Programme

im Wintersemester 2019/2020

erstellt am 28/03/24

pre311 - Renewable Energy Basics 5
pre314 - Energy Meteorology & Storage Technologies 7
pre315 - Energy Systems & Society 9
pre325 - Wind Potential, Aerodynamics & Loading of Wind Turbines 11
pre326 - Wind Turbine Design, Electrical & Control Issues, Certification 13
pre327 - Wind Farm Technology, Economics & Environmental Issues 15
pre328 - Mini Project & Wind Farm Study 17
pre331 - Ocean Energy Resources 19
pre332 - Modelling and Control of Ocean Energy Systems 20
pre333 - Ocean Energy Systems Technologies 21
pre334 - Economics, Policy and Environment 23
pre335 - Project 24
pre351 - Photovoltaic Cell Technology 25
pre352 - Advanced Photovoltaic Cell Design 27
pre353 - Photovoltaics: Economics, Policy and Environment 28
pre354 - Photovoltaic System Technology 29
pre364 - Thermal Energy Storage 31
pre365 - Fundamentals 33
pre366 - Solar Low Temperature 35
pre367 - Solar High Temperature 36
pre371 - Distributed Generation 38

pre372 - Generation and Storing Technologies 39
pre373 - Control Techniques and Renewable Energy Integration Systems 40
pre374 - Power Grid Analysis and Studies 42
pre375 - Smart Grids 44
pre376 - Standards and Electric Markets 46
pre377 - Project 47
pre381 - Processes, models & modelling 48
pre382 - Biochemical conversion 49
pre383 - Thermochemical conversion 50
pre384 - New Business 51
pre355 - Development and Implementation 52
pre385 - Sustainable Fuel Supply Chains 53
pre386 - Bio Energy Conversion 54
pre387 - Power-to-Hydrogen 55
pre400 - Fundamentals for Renewable Energy 56
pre405 - Energy Resources and Systems 57
pre410 - Renewable Energy Technologies I 58
pre420 - Fundamentals 63
pre421 - Simulation and System Optimization 64
pre422 - Energy 65
pre423 - Materials 66
pre424 - Project, case study and innovation 67

pre430 - Introduction to Electric Power Systems and power electronics 68
pre431 - Distributed energy resources (DER) 69
pre432 - Renewable Energy Integration 70
pre433 - DER Impact on EPS 71
pre434 - Smart Grids solutions 72
pre435 - Energetic Markets 73
phy641 - Energy Resources & Systems 74
mam - Master´s Thesis Module 76

Mastermodule

pre311 - Renewable Energy Basics

Module label	Renewable Energy Basics
Modulkürzel	pre311
Credit points	6.0 KP
Workload	180 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	• Agert, Carsten (module responsibility) • Peinke, Joachim (module responsibility) • Behrendt, Tanja (Module counselling) • Knecht, Robin (Module counselling) • Holtorf, Hans-Gerhard (Module counselling) • Ohland, Jörg (Module counselling) • Ziethe, Paul (Module counselling)
Prerequisites	
Skills to be acquired in this module	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
Module contents	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
Literaturempfehlungen	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, Calififorniа; 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	
Links			
Language of instruction		English	
Duration (semesters)		1 Semester	
Module frequency		jährlich	
Module capacity		unlimited	
Examination	Prüfungszeiten		Type of examination
Final exam of module	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		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)
Form of instruction	Seminar		
Frequency			

pre314 - Energy Meteorology & Storage Technologies

Module label	Energy Meteorology & Storage Technologies
Modulkürzel	pre314
Credit points	7.0 KP
Workload	210 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	• Heinemann, Detlev (module responsibility) • Agert, Carsten (Module counselling) • Knecht, Robin (Module counselling) • Steinberger-Wilckens, Robert (Module counselling)
Prerequisites	
Skills to be acquired in this module	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
Module contents	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
Literaturempfehlungen	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.
Links		
Language of instruction		English
Duration (semesters)		1 Semester
Module frequency		jährlich
Module capacity		unlimited

Examination	Prüfungszeiten	Type of examination
Final exam of module	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	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)
Form of instruction	Seminar	
Frequency		

pre315 - Energy Systems & Society

Module label	Energy Systems & Society
Modulkürzel	pre315
Credit points	4.0 KP
Workload	120 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	• Agert, Carsten (module responsibility) • Heinemann, Detlev (module responsibility) • Golba, Michael (Module counselling) • Malz, Simone (Module counselling)
Prerequisites	
Skills to be acquired in this module	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
Module contents	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)
Literaturempfehlungen	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
Links		
Language of instruction		English
Duration (semesters)		1 Semester
Module frequency		jährlich
Module capacity		unlimited

Examination	Prüfungszeiten	Type of examination
Final exam of module	Energy Systems: At the end of lecture period (end of January) Energy Economics: After end of lectures (mid-December) Country report: During Semester	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)

Form of instruction	Seminar
Frequency	

pre325 - Wind Potential, Aerodynamics & Loading of Wind Turbines

Module label	Wind Potential, Aerodynamics & Loading of Wind Turbines
Modulkürzel	pre325
Credit points	7.5 KP
Workload	225 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	At the completion of this module, the student will: • possess advanced knowledge on wind potential, aerodynamics and loading of wind turbines • be skilled in simulation programs for design and control of Wind Turbines (GH Bladed), practical experience • be skilled in wind potential evaluation, wind farm design and environmental impacts using simulation programs (GH WindFarmer), • have an understanding of economic parameters for a successful project realisation At the completion of this module, the student will: - possess advanced knowledge on wind potential, aerodynamics and loading of wind turbines - be skilled in simulation programs for design and control of Wind Turbines (GH Bladed), practical experience - be skilled in wind potential evaluation, wind farm design and environmental impacts using simulation programs (GH WindFarmer), - have an understanding of economic parameters for a successful project realisation
Module contents	1. Introduction - Status of Wind Energy - Status of European Wind Energy and R&D 2. Advanced Wind Structure and Statistics - Gusts and gust probability distributions - Effects of topography 3. Evaluation of Wind Energy Potential - Wind modelling in flat and complex terrain - Wind energy siting approaches 4. Wind Turbine Aerodynamics - Advanced methods - Aerodynamic stall - Unsteady aerodynamics - Vortex wake structure - Advanced wake models - Optimum design of wind turbine blades 5. Static and Dynamic Loading of Wind Turbines - Aerodynamic and gravity loading - Inertial and structural loads - Aeroelastic modelling - Fatigue of wind turbine blades
Literaturempfehlungen	European Wind Energy Association: Wind Energy - The Facts. 2004. J.F. Manwell, J.G.McGowan, A.L.Rogers, J.Willey and Sons: Wind Energy Explained – Theory, Design and Application. 2002. R. Gasch, J. Twele, James and James: Wind Power Plants - Fundamentals, Design, Construction and Operation. 2002. M. J. Pasqualetti, P. Gipe, R.W. Righter (eds): Wind Power in View. Academic Press, 2002. R.Y. Redlingen, P.D. Andersen, P.E. Morthorst: Wind Energy in the 21st Century. UNEP, 2002. T. Burton, D. Sharpe, N. Jenkins, E. Bossanyi: Wind Energy Handbook. John Wiley and Sons, 2001. P. Gipe: Wind Energy Comes of Age'. John Wiley and Sons, 1995.
Links	
Language of instruction	English
Duration (semesters)	1 Semester
Module frequency	jährlich
Module capacity	unlimited

Examination	Prüfungszeiten	Type of examination
Final exam of module	Exam week (end of May)	Written exam (3 hours)
Form of instruction	Seminar	
Frequency		

pre326 - Wind Turbine Design, Electrical & Control Issues, Certification

Module label	Wind Turbine Design, Electrical & Control Issues, Certification
Modulkürzel	pre326
Credit points	7.5 KP
Workload	225 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	At the completion of this module, the student will: - possess advanced knowledge on wind turbine design, electrical and control issues - be skilled in Wind potential evaluation, Wind farm design and environmental impacts using simulation programs (GH WindFarmer), practical experience - be skilled in performance testing and modelling of wind turbines
Module contents	1. Electrical Conversion Systems - Synchronous and induction generators - Direct drive generators - Constant and variable speed systems 2. Wind turbines control - Aerodynamic power control (stall, pitch, yaw) - Electromagnetic torque control - Control – dynamic analysis and stability - Control strategies 3. Design of wind turbines - Important factors - Design options - Design parameters - Design of components - System design - Megawatt scale design - Offshore design 4. Performance Testing and Modelling - Measurements under controlled conditions - Field testing instrumentation 5. Measurements - anemometers - calibration 6. Electrical Integration - Weak grids - Power quality - Network costs and benefits 7. Large scale integration - Technical, economical and policy issues - Grid connection requirements, infrastructure - Economic aspects 8. Standards and Certification - WT certification - International standards
Literaturempfehlungen	European Wind Energy Association: Wind Energy - The Facts. 2004. J.F. Manwell, J.G.McGowan, A.L.Rogers, J.Willey and Sons: Wind Energy Explained – Theory, Design and Application. 2002. R. Gasch, J. Twele, James and James: Wind Power Plants - Fundamentals, Design, Construction and Operation. 2002. M. J. Pasqualetti, P. Gipe, R.W. Righter (eds): Wind Power in View. Academic Press, 2002. R.Y. Redlingen, P.D. Andersen, P.E. Morthorst: Wind Energy in the 21st Century. UNEP, 2002. T. Burton, D. Sharpe, N. Jenkins, E. Bossanyi: Wind Energy Handbook. John Wiley and Sons, 2001. P. Gipe: Wind Energy Comes of Age'. John Wiley and Sons, 1995. S. Heier: Grid Integration of Wind Energy Conversion Systems. John Wiley and Sons, 1998. L.L. Freris (ed): Wind Energy Conversion Systems. Prentice Hall, 1990.
Links	
Language of instruction	English
Duration (semesters)	1 Semester
Module frequency	jährlich
Module capacity	unlimited

Examination	Prüfungszeiten	Type of examination
Final exam of module	Exam week (end of May)	Written exam (3 hours)
Form of instruction	Seminar	
Frequency		

pre327 - Wind Farm Technology, Economics & Environmental Issues

Module label	Wind Farm Technology, Economics & Environmental Issues
Modulkürzel	pre327
Credit points	7.5 KP
Workload	225 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	At the completion of this module, the student will: - possess advanced knowledge on wind farm design - possess advanced knowledge on economics and environmental issues - be skilled in wind farm design and environmental impacts using simulation programs (GH WindFarmer), practical experience - have an understanding of economical parameters to successful project realisation
Module contents	1. Wind Farm Technology Issues - Wind exploitation in wind farms - Energy predictions and optimization - Balance of plant - Wind farms electrical design - Wind Farm design, wake effect (simple and advanced wake models, numerical methods - CFD approach) 2. Economics of WT and Externalities - Calculation methods - Current plant costs - Wind energy prices - The value of wind energy - External costs - Future price trends 3. Environmental Issues - Environmental benefits - Environmental effects - Amenity (land use, visual impact) - Technical analysis of noise and electromagnetic interference - Ecology (birds) - Consumption of energy and materials 4. Market development and status of industry - Characteristics of the EU industry - Present status of wind power - Market description - Market predictions - Wind energy targets - Wind energy market incentives in Europe 5. Offshore - Turbine modelling - Support structures – foundation - Wind farms aspects - Grid connections 6. Wind energy in urban areas 7. Wind forecast - Introduction to Coupled Ocean / Atmosphere Mesoscale Prediction System (COAMPS)
Literaturempfehlungen	European Wind Energy Association: Wind Energy - The Facts. 2004. J.F. Manwell, J.G.McGowan, A.L.Rogers, J.Willey and Sons: Wind Energy Explained – Theory, Design and Application. 2002. R. Gasch, J. Twele, James and James: Wind Power Plants - Fundamentals, Design, Construction and Operation. 2002. M. J. Pasqualetti, P. Gipe, R.W. Righter (eds): Wind Power in View. Academic Press, 2002. R.Y. Redlingen, P.D. Andersen, P.E. Morthorst: Wind Energy in the 21st Century. UNEP, 2002. T. Burton, D. Sharpe, N. Jenkins, E. Bossanyi: Wind Energy Handbook. John Wiley and Sons, 2001. P. Gipe: Wind Energy Comes of Age'. John Wiley and Sons, 1995. S. Heier: Grid Integration of Wind Energy Conversion Systems. John Wiley and Sons, 1998. L.L. Freris (ed): Wind Energy Conversion Systems. Prentice Hall, 1990. T. Ackermann: Wind Power in Power Systems. Wiley, 2005. EWEA: Large scale integration of wind energy in the European power supply: Analysis, issues and recommendations. December 2005.

Links		
Language of instruction	English	
Duration (semesters)	1 Semester	
Module frequency	jährlich	
Module capacity	unlimited	
Examination	Prüfungszeiten	Type of examination
Final exam of module	Exam week (end of May)	Written exam (3 hours)
Form of instruction	Seminar	
Frequency		

pre328 - Mini Project & Wind Farm Study

Module label	Mini Project & Wind Farm Study
Modulkürzel	pre328
Credit points	7.5 KP
Workload	225 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	This module is split in two parts. The first one is the Mini Project and the second is the Wind Farm Study. During the mini-project students are skilled in preparation, writing and presentation of a scientific project, of their choice. They learn how to make a bibliographic research, organise their references, focus on a special topic, describe the problem, collect data, and draw conclusions. Finally, they gain experience on presentations. Students are encouraged to connect their mini-project topic with their internship. In parallel, during the wind farm study, students make their own study on the design of a wind farm. Individual data are provided, together with the necessary computational tools to be used in the various steps of the study (Wind data, wind turbine, energy calculations, Wind farm layout, Integration issues and financial evaluation)
Module contents	1. Mini Project Students are encouraged to realize a mini project in a subject of their interest. Through this project, students are focus on a special topic of wind energy: - Aerodynamics / Aero-elasticity / Aero-acoustics / Loads, - Wind forecasting / capacity credit (short term – long term), - Hybrid solutions for isolated systems, - Wind farms design / wake effect, - Small scale wind turbines for rural/urban applications - Financial issues / External costs / Green certificates / CO2 Emissions taxes - Control - Analysis of market development - Off shore (design, development, wind assessment) - Measuring methods and monitoring - Grid integration / electrical issues - Operation and damages - Environmental issues The typical form of the mini-project's report submitted is: - Abstract – key words - Introduction / scope /objectives - Bibliographic research - Methodology - Computational part - Results - Discussion / conclusions 2. Wind Farm study The steps of the wind farm study is consists of: - Wind data analysis (statistics, wind rose design), - Wind turbine design for the specific site using Blade Element Momentum theory - Energy calculations for the specific wind turbine and wind data, using a cost model for the minimization of the LCOE - Wind farm's layout and wake effect calculation - Integration issues for specific autonomous power system (wind energy curtailment, capacity credit) - Financial evaluation (IRR, NPV, PBP)
Literaturempfehlungen	European Wind Energy Association: Wind Energy - The Facts. 2004. J.F. Manwell, J.G.McGowan, A.L.Rogers, J.Willey and Sons: Wind Energy Explained – Theory, Design and Application. 2002. R. Gasch, J. Twele, James and James: Wind Power Plants - Fundamentals, Design, Construction and Operation. 2002. M. J. Pasqualetti, P. Gipe, R.W. Righter (eds): Wind Power in View. Academic Press, 2002. R.Y. Redlingen, P.D. Andersen, P.E. Morthorst: Wind Energy in the 21st Century. UNEP, 2002. T. Burton, D. Sharpe, N. Jenkins, E. Bossanyi: Wind Energy Handbook. John Wiley and Sons, 2001. P. Gipe: Wind Energy Comes of Age'. John Wiley and Sons, 1995. S. Heier: Grid Integration of Wind Energy Conversion Systems. John Wiley and Sons, 1998. L.L. Freris (ed): Wind Energy Conversion Systems. Prentice Hall, 1990. T. Ackermann: Wind Power in Power Systems. Wiley, 2005.
Links	
Language of instruction	English
Duration (semesters)	1 Semester
Module frequency	jährlich
Module capacity	unlimited
Type of module	Wahlpflicht / Elective
Module level	MM (Mastermodul / Master module)

Examination	Prüfungszeiten	Type of examination
Final exam of module	Mini Project: Submission deadline end of May Wind Farm Study: Submission deadline end of April	Mini Project (50%): Written report up to 3,500 words, Presentation (15-20 minutes presentation plus discussion) Wind Farm Study (50%): Written report (15-20 pages)

Form of instruction	Seminar

Frequency

pre331 - Ocean Energy Resources

Module label	Ocean Energy Resources
Modulkürzel	pre331
Credit points	6.0 KP
Workload	180 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	At the completion of this module, the student will: - have an understanding of the physical mechanisms in the ocean which are on the basis of the generation of surface waves, tides and currents, and their effects, as well as the biological processes that may affect or be affected by ocean energy devices. - be familiar with the statistic description of waves and currents - be able to use the statistical information in order to make evaluation of the energy resource - be able to use GIS for site selection characterization.
Module contents	- Introduction to the ocean environment: ocean water and geology; ocean circulation and stratification; ocean habitat; ocean economy. - Ocean surface waves: linear wave theory (regular and random waves); wave spectrum; wave energy resource: parametrical characterisation of ocean waves, nearshore wave transformation, wave measurement and modelling. - Other sources of ocean energy: ocean tidal currents (current measurement; current turbulence; current energy resource); ocean thermal energy conversion; ocean salinity gradient energy resource. - Site selection and characterization for ocean energy systems: criteria on energy resource, expected cost levels, water depth, seabed geology and ecology, distance to shore, ports, O&M bases and electrical grid, marine environmental issues.
Literaturempfehlungen	Apel, J.R.: Principles of Ocean Physics. Academic Press, 1987, 631 pp. Bakus, G.: Quantitative analysis of marine biological communities. Wiley, 2007. Boon, J.: Secrets of the tide: Tide and tidal current analysis and predictions, strom surges and sea level trends. West Sussex, UK: Horwood Publishing, Ltd, 2004. 300 pp. Cartwright, D. E.: Oceanic tides. Rep. Prog. Phys., 1977, 40(6), 665–708. Goda, Y.: Random Seas and Design of Marine Structures. University of Tokyo Press, Japan, 1985. 323 pp. Sarpkaya, T. and M. Isaacson: Mechanics of Wave Forces on Offshore Structures. Van Nostrand Reinhold Company, New York, U.S.A., 1981. 651 pp. Young, I.R.: Wind Generated Ocean Waves. Elsevier Science Ltd, Oxford, UK, 1999. 288 pp. Roberts, J.: Marine Environment protection and biodiversity conservation. Springer-Verlag Berlin Heidelberg, 2007. 264 pp. Lerman, M.: Marine Biology: environment, diversity and ecology. Addison-Wesley 1999.
Links	
Language of instruction	English
Duration (semesters)	1 Semester
Module frequency	jährlich
Module capacity	unlimited

Examination	Prüfungszeiten	Type of examination
Final exam of module	Exam: end of lecture period (early June) Report: deadline end of May	Written exam (60%): 2.5 hours Written report (40%): essay on a chosen topic, 10-20 pages

Form of instruction	Seminar
Frequency	

pre332 - Modelling and Control of Ocean Energy Systems

Module label	Modelling and Control of Ocean Energy Systems
Modulkürzel	pre332
Credit points	6.0 KP
Workload	180 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	At the completion of this module, the student will: - be familiar with the linear hydrodynamic theory of wave energy systems - be familiar with the hydrodynamic theory of marine current turbines (BEM) - be introduced to advanced numerical hydrodynamic modelling of wave and current systems and control simulation - be familiar with experimental testing and monitoring of OE systems - acquire basic knowledge of other forms of ocean energy and their systems as OTEC and salinity gradients.
Module contents	- Wave energy systems: Types of wave energy converters. Linear wave structure interactions. Frequency domain analysis. Hydrodynamic coefficients and their computation. Time domain analysis. Phase control. Arrays. Model testing techniques. Marine current turbines. Types of marine current turbines. - Hydrodynamic models: Blade Element Momentum (BEM), Lifting line (LL), Integral Boundary Element Method (IBEM). Hydrofoil data and analysis. Cavitation and strength. Design criteria. Multiple turbine interaction. - Other types of energy systems: Ocean Thermal Energy Conversion (OTEC). Energy from salinity gradients. Laboratory - Wave Flume of the Civil Engineering Department of IST: Characterization of systems of regular and irregular 2D waves. Energy spectra. (Duration 3 h). - Wave Flume of the Civil Engineering Department of IST: Characterization of a floating body response RAO in a system of regular 2D waves. (Duration 3 h).
Literaturempfehlungen	J. Falnes: Ocean Waves and Oscillating Systems. Cambridge: Cambridge University Press, 2002. G. Thomas: The theory behind the conversion of ocean wave energy: a review. In: (J. Cruz, editor) Ocean Wave Energy. Berlin: Springer, 2008, p. 41-91. Numerical and experimental modelling of WECs. In: (J. Cruz, editor) Ocean Wave Energy. Berlin: Springer, 2008, p. 133-188. A. A. Sayigh (Editor): Comprehensive Renewable Energy, vol. 8, Ocean Energy, Elsevier, in press, 2012. A. F. O. Falcão: Wave energy utilization: a review of the technologies. Renewable and Sustainable Energy Reviews, vol. 14, p. 899-918, 2010. Lecture Notes. To be produced. Jack Hardisty: The Analysis of Tidal Stream Power, John Wiley & Sons, 2009, ISBN 9780470724514. Roger H. Charlier, Charles W. Finkl: Ocean Energy: Tide and Tidal Power, Springer, 2009, ISBN: 3540779310
Links	
Language of instruction	English
Duration (semesters)	1 Semester
Module frequency	jährlich
Module capacity	unlimited

Examination	Prüfungszeiten	Type of examination
Final exam of module	Written exam (Wave Energy): early April Written exam (Marine Current Turbines): early June Written report (Lab): mid-May	Written exam (40%): Wave Energy, 2.5 hours Written exam (50%: Marine Current Turbines, 2.5 hours Written report (10%): Lab report, 10 - 20 pages

Form of instruction	Seminar
Frequency	

pre333 - Ocean Energy Systems Technologies

Module label	Ocean Energy Systems Technologies		
Modulkürzel	pre333		
Credit points	7.5 KP		
Workload	225 h		
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule		
Zuständige Personen			
Prerequisites			
Skills to be acquired in this module	At the completion of this module, the student will: - be familiar with the state of the art of electro-mechanical power take-off equipment used in wave energy converters and marine current turbines; - be familiar with mooring and anchoring systems; - be familiar with the design and configuration of farms; - be capable to distinguish the different components and designs of offshore electrical grids; - acquire basic knowledge on the requirements to deploy, operate and maintain the wave and current energy system; - be aware of maritime safety issues.		
Module contents	- Principle of operation and components of air turbines, water turbines, high-pressure hydraulic systems, linear and rotating electrical generators, and energy storage in ocean energy. - Classification of offshore structures; loads, cost and materials of mooring and anchoring systems; description of anchoring and foundations systems; taut and slack-mooring systems; and mooring configurations in arrays. - Principles of interference of WEC arrays and layout optimization methods. - Analysis of tidal turbines arrays. - Offshore electrical grid structure and components, cable technologies, electrical designs (HVDC vs AC), interaction with the local electricity network, integration into the National grid, examples/case studies. - Routine and non-routine offshore operations; management systems; maintenance procedures, risk assessment and inspection plans; and case studies. - Introduction to offshore operations; vessels, equipment and personnel; method planning and permitting; principles, legislation and standards of safety management. Laboratory: - Fluid Mechanics Laboratory of the Mechanical Engineering Department of IST: Testing of an air turbine for use in OWC systems. (Duration 3 h). - Electrical Machinery Laboratory of the Electrical and Computer Engineering Department of IST: laboratory practice on electrical generators. (Duration 3 h).		
Literaturempfehlungen	A. Sayigh: Comprehensive Renewable Energy: Ocean Energy. Elsevier, 2012. J. Cruz: Ocean Wave Energy: Current Status and Future Perspectives, 2008. S. Chakrabarti: Handbook of offshore engineering. Elsevier, Vol. 2, 2005. Carbon Trust: Guidelines on design and operation of wave energy converters, 2005. EMEC: Guidelines for Health and Safety in the Marine Energy Industry, 2008. R. E. Harris et al: Mooring systems for wave energy converters: A review of design issues and choices. B. Child: On the configuration of arrays of floating wave energy converters. PhD thesis, University of Edinburgh, 2011. I. Alegría et al: Transmission alternatives for offshore electrical power. Renewable and Sustainable Energy Reviews 13, 1027–1038, 2009. K. Thorburn et al: Wave energy transmission system concepts for linear generator arrays. Ocean Engineering 31, 1339–1349, 2004.		
Links			
Language of instruction	English		
Duration (semesters)	1 Semester		
Module frequency	jährlich		
Module capacity	unlimited		
Examination	Prüfungszeiten	Type of examination	
Final exam of module	Exam week (mid-June)	Written exam (3 hours)	
Form of instruction	Seminar		
Frequency			

pre334 - Economics, Policy and Environment

Module label	Economics, Policy and Environment		
Modulkürzel	pre334		
Credit points	4.5 KP		
Workload	135 h		
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule		
Zuständige Personen			
Prerequisites			
Skills to be acquired in this module	At the completion of this module, the student will: - be familiar with the basic economic analysis of ocean energy systems including the cost, financing and economic evaluation - acquire basic knowledge on the general policy issues regarding ocean energy systems and more detailed knowledge on the licensing and permitting procedures for installation of OE systems and enabling mechanisms as funding, feed-in tariffs and tax incentives - be able to perform simple environmental impact studies for OE systems.		
Module contents	- Marine spatial planning, concession regimes of marine areas; consenting and licensing of marine farms; feed-in tariffs, green certificates, tax incentives and other financial support mechanics. - Economic analysis of a marine farm: present and future cost of energy (LCOE, externalities) - the role of offshore energy; characterization of offshore renewable costs (CAPEX and OPEX); project financing: principles (equity, debt ratio), parameters (discount rate, return period, NPV, IRR), tools (Retscreen, etc.) and risk assessment. - Environmental and socio economic impact assessment and monitoring: EIA objectives, process and requirements; public consultation and conflict of uses management; environmental monitoring; life-cycle assessment.		
Literaturempfehlungen	Paillard, M., Lacroix, D., Lamblin, V.: Marine Energy Renewables – Prospective Foresight Study for 2030, Éditions Quae, 2009, ISBN 9782759201839. Mendonça, M.: Feed-In Tariffs – Accelerating the Deployment of Renewable Energy, Earthscan, 2007, ISBN 9781844077885. Soares, I., Moreira J., Pinho, C. e Couto J.: Análise Financeira de Projectos, Edições Sílabo, 2007, Portugal. EWEA: Economics of wind Energy, http://www.ewea.org/fileadmin/ewea_documents/documents/00_POLICY_document/Economics_of_Wind_Energy__March_2009_.pdf IEA: Projected Costs of Generating Electricity. 2010. Carbon Trust: Accelerating marine energy, 2011. Ernst & Young and DECC (UK): Cost of and financial support for offshore wind, 2009.		
Links			
Language of instruction	English		
Duration (semesters)	1 Semester		
Module frequency	jährlich		
Module capacity	unlimited		
Examination	Prüfungszeiten	Type of examination	
Final exam of module	Exam: end of lecture period (early June); Report: deadline end of May	Written exam (60%): 2.5 hours Written report (40%): essay on a chosen topic, 15-20 pages	
Form of instruction	Seminar		
Frequency			

pre335 - Project

Module label		Project	
Modulkürzel		pre335	
Credit points		6.0 KP	
Workload		180 h	
Verwendbarkeit des Moduls		• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule	
Zuständige Personen			
Prerequisites			
Skills to be acquired in this module		With the completion of this module, the student will bring into practice the knowledge acquired through a case study in the form of a specific small project.	
Module contents		This course integrates the knowledge previously acquired by the students regarding the resource evaluation, and the conversion processes. At the end of the course each student should deliver an outline project to explore wave energy in a given site and with a given technology.	
Literaturempfehlungen		Literature of the other modules	
Links			
Language of instruction		English	
Duration (semesters)		1 Semester	
Module frequency		jährlich	
Module capacity		unlimited	
Examination	Prüfungszeiten		Type of examination
Final exam of module	Deadline: End of June		Written report & Presentation: 30 pages written report; 20 min presentation plus 40 min discussion
Form of instruction	Seminar		
Frequency			

pre351 - Photovoltaic Cell Technology

Module label	Photovoltaic Cell Technology
Modulkürzel	pre351
Credit points	10.0 KP
Workload	300 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	After completing the module, the student will - have a critical understanding of the physical principles relating to the operation and design of photovoltaic cells. - be able to compare and analyse the design and operation of the main types of photovoltaic cells. - have a critical understanding of the effect of material purity and crystallinity on the device performance. - be able to compare and evaluate different methods for the fabrication of photovoltaic cells in terms of device properties and manufacturing issues. - have a critical understanding of the principles of operation and design of photovoltaic modules. - be able to compare and evaluate methods for the fabrication of photovoltaic modules, including performance and manufacturing issues.
Module contents	1. Physics of Solar Cell Devices: - Solar spectrum, solar constant and air mass. - Important semiconductors. Important solar cell devices. - Drude theory. Breakdown of classical theory. Quantum theories of conduction: E-k curves, energy bandgap and effective masses, direct and indirect transitions. - Carrier statistics in equilibrium - intrinsic and extrinsic behaviour. - Carrier transport, mobilities and diffusion coefficients, scattering mechanisms. Hall effect. - Non-equilibrium behaviour: direct, indirect and surface recombination, carrier lifetime and diffusion length. - Current density and continuity equations, examples of solutions. - Optical and thermal properties of semiconductors. Antireflection coatings. p-n junction in equilibrium: built in voltage, depletion region and depletion capacitance. Derivation of I-V characteristics in the dark. - Spectral response. Ideal diode under illumination: open circuit voltage, short circuit current, solar conversion efficiency, fill factor. - Variations of photocurrent and open circuit voltage with incident light intensity. Optimum energy bandgap of a solar cell. - Loss mechanisms. Introduction to tandem/ multijunction concepts. - Real diodes: recombination and generation in the depletion region, effects of series and leakage resistance on ideal behaviour. Schottky diodes and Ohmic contacts. Interface states. - Heterojunctions: Anderson model, current transport models, heterojunction window effect. - Effects of temperature and radiation on solar cell performance. 2. Solar Cell Fabrication Technologies - Introduction: Important semiconductors and solar cell devices. - Important semiconductor parameters. Effects of lattice vibrations, impurity atoms and other crystal imperfections on these parameters. - Purification of silicon: chemical, zone refining and gettering. Segregation coefficient. - Crystal growth: Bridgmann methods, Czochralski method and Floating Zone Methods. - Advanced epitaxial growth methods: MBE, MOCVD, LPE AND VPE. - Low cost thin film deposition methods: thermal evaporation methods, sputtering methods and wet chemical methods, e.g electrodeposition, autocatalytic deposition, spray pyrolysis and screen printing. - Compensation doping: alloying, solid state diffusion and ion implantation. Dielectric deposition - thermal oxidation of silicon, LPCVD and PECVD silicon oxide and nitrides. - Photolithography. Etching - wet and dry methods. - Overview of characterisation techniques for semiconductor materials and cells. - Overview of design of silicon, III-V and thin film solar cells for terrestrial and space applications and the design and fabrication of photovoltaic modules made from these cells.
Literaturempfehlungen	S.M.Sze and Kwok K. Ng: Physics of Semiconductor Devices, Wiley, 2006 Lewis Fraas and Larry Partain (eds): Solar Cells and Their Applications, Second Edition, Wiley, 2010. Journals of „Solar Energy Materials and Solar Cells" and „Progress in Photovoltaics". Proceedings of IEEE Photovoltaic Specialist Conferences. Proceedings of European Photovoltaic Solar Energy Conferences.
Links	
Language of instruction	English
Duration (semesters)	1 Semester
Module frequency	jährlich
Module capacity	unlimited
Type of module	Wahlpflicht / Elective

Module level	MM (Mastermodul / Master module)	
Examination	Prüfungszeiten	Type of examination
Final exam of module	At the end of the semester.	Written exam (60%, 3 hours) Laboratory Reports (40%)
Form of instruction	Seminar	
Frequency		

pre352 - Advanced Photovoltaic Cell Design

Module label	Advanced Photovoltaic Cell Design
Modulkürzel	pre352
Credit points	5.0 KP
Workload	150 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	After completing the module, the student will be able to - Critically appraise the choice of semiconductors used and the design and fabrication methods used to produce an advanced PV device. - Critically appraise the characterisation methods used with semiconductor materials and with PV devices. - Perform a literature review on advanced PV devices to a professional standard. - Present data and information both verbally and in the written form to a professional standard.
Module contents	1. Introduction - Flat plate modules. Concentrator solar cells. Multijunction concepts. - Overview of types of solar cell developed - status of the technologies. 2. Advanced Devices - Crystalline Silicon Devices: High efficiency crystalline silicon designs incorporating surface passivation, light trapping and vertical contacts. Cost reduction strategies: ribbon fed growth and thin film silicon devices. - Polycrystalline silicon. - III-V Devices: Heteroface cell. Radiation resistance. GaAs, InP and GaSb-based devices. Designs for use under high concentration. - Space applications. Physics of multijunction cells. Quantum well devices. - Thermophotovoltaic devices. - Thin Film Solar Cells: Amorphous silicon. CdTe and chalcopyritebased solar cells. Typical cell structures. Methods of fabrication. Applications. Polymer cells, Gratzel cells. 3. Advanced Characterisation Methods - Material characterisation: X-ray diffraction, electron and ion beam characterisation methods, optical characterisation, Van der Pauw length. - Device Characterisation: DLTS, photoluminescence and PAS. - Solar simulators. - Measurement of fill-factor, solar conversion efficiency and spectral response. - I-V-T and C-V-f measurements. Radiation damage 4. Literature Review This will be undertaken for one of the following topics: crystalline silicon devices, III-V devices or thin film devices.
Literaturempfehlungen	S.M.Sze and Kwok K. Ng: Physics of Semiconductor Devices, Wiley, 2006 Lewis Fraas and Larry Partain (eds): Solar Cells and Their Applications, Second Edition, Wiley, 2010. Journals of „Solar Energy Materials and Solar Cells" and „Progress in Photovoltaics“. Proceedings of IEEE Photovoltaic Specialist Conferences. Proceedings of European Photovoltaic Solar Energy Conferences.
Links	
Language of instruction	English
Duration (semesters)	1 Semester
Module frequency	jährlich
Module capacity	unlimited

Examination	Prüfungszeiten	Type of examination
Final exam of module	At the end of the semester	Written report (literature review): The module assessment is in the form of a review of approximately 3,000 words, chosen by the student from a list of PV device categories.

Form of instruction	Seminar
Frequency	

pre353 - Photovoltaics: Economics, Policy and Environment

Module label	Photovoltaics: Economics, Policy and Environment		
Modulkürzel	pre353		
Credit points	5.0 KP		
Workload	150 h		
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule		
Zuständige Personen			
Prerequisites			
Skills to be acquired in this module	After completing the module, the student will be able to: - Critically analyse the international policies relating to photovoltaics and other energy technologies focusing on the strategic, environmental and economic implications of these policies - Perform an economic and/or environmental analysis of a photovoltaic system.		
Module contents	1. Economic Analysis - Economic theory - net present value, effect of interest rates, definition of capital and recurrent costs - Production economics - definition of production costs, economies of scale, projected manufacturing costs - Subsidies and tariff issues - effect of electricity supply costs on system viability - Financing mechanisms - review of international financing mechanisms for purchase and operation of systems 2. Policy Issues - Market development and projections - Review and appraisal of government policies and market development schemes - Security of supply - Climate change issues - Energy for development - role of photovoltaics 3. Environmental Impact Assessment - Process definition for module production - Hazard assessment - EC environmental directives - Embodied energy calculations - Energy payback times and ratios - Calculation of associated CO2 and other emissions		
Literaturempfehlungen	Journal of "Progress in Photovoltaics" Proceedings of European Photovoltaic Solar Energy Conferences Proceedings of IEEE Photovoltaic Specialist Conferences IEEEXplore database Environmental data sources Government literature (including European Commission and international) on renewable energy promotion IEA Photovoltaic Power Systems Programme reports		
Links			
Language of instruction	English		
Duration (semesters)	1 Semester		
Module frequency	jährlich		
Module capacity	unlimited		
Examination	Prüfungszeiten		Type of examination
Final exam of module	At the end of the semester		Written report (essay, approximately 3,000 words) and Presentation (10 minutes)
Form of instruction	Seminar		
Frequency			

pre354 - Photovoltaic System Technology

Module label	Photovoltaic System Technology
Modulkürzel	pre354
Credit points	10.0 KP
Workload	300 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	After completing the module, the student will be able to: - Assess the system requirements for both grid connected and stand alone applications. - Design and develop a PV system by evaluating complex customer needs in relation to an application - Critically evaluate the performance of a PV system in comparison to a theoretical model of such a system, calculating yields and efficiencies - Analyse the main system losses and compare methods for minimising these for various system designs
Module contents	1. Basic systems design - Photovoltaic (PV) arrays, support structures - Electrical Connections and wiring issues - BOS components - Stand alone and grid connected systems - System sizing 2. Stand-alone systems - Applications - Performance assessment and sizing - Standards and regulations 3. Grid connected systems - electrical - Inverter systems and electrical supply issues - Grid connection regulations - Harmonic content, reactive power, and wiring issues 4. Grid connected systems - large scale - Design of large scale systems - Case studies 5. Grid connected systems - building integrated - System design and sizing - Energy in buildings and building components - Installation and operation - Case studies 6. Concentrator systems - Design of concentrator systems - Operation and maintenance 7. Monitoring and performance analysis - Monitoring specifications - Yield and performance ratio, and MTBF - Operational issues and maintenance 8. Standards and regulations - Standards for construction and operation - Regulations governing system design and operation - Health and safety issues 9. Space systems - Array configurations - Quality control and assessment - Design of systems - BOL and EOL design tradeoffs
Literaturempfehlungen	Messenger, R., & Ventre, J.:. Photovoltaic Systems Engineering, 3rd edition, Taylor & Francis, 2010. Wenham, S.: Applied Photovoltaics, 3rd edn., Earthscan, 2011. Journals: - Progress in Photovoltaics - Renewable Energy - Various IEEE journals relating to electrical engineering Databases and Websites - IEA PV Power Systems Programme (www.iea-pvps.org) - European Photovoltaic Industries Association (http://www.epia.org/home/) - PVGIS web site (http://re.jrc.ec.europa.eu/pvgis/) Other Resources - Measurement data from system trials - PVSyst software

Links		
Language of instruction	English	
Duration (semesters)	1 Semester	
Module frequency	jährlich	
Module capacity	unlimited	
Examination	Prüfungszeiten	Type of examination
Final exam of module	At the end of the semester	Written exam (60%, 3 hours) Written report (40%, design assignment): Feasibility report, maximum of 10 pages plus technical appendices
Form of instruction	Seminar	
Frequency		

pre364 - Thermal Energy Storage

Module label	Thermal Energy Storage
Modulkürzel	pre364
Credit points	4.0 KP
Workload	120 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	After the completion of the module the student will - be familiar with main storage materials and technologies and will be able to choose which one is the most adapted to a specific solar application. - have an understanding of the basic physical phenomena relevant to the principles of operation and design of thermal energy storages. - have an understanding of the principles of operation and design of thermal energy storages. - have an understanding of the need to define properly the functionalities of the TES. - acquire the knowledge of the main technologies and materials used in TES. - acquire the awareness of the importance of considering the relevant integration of TES in the whole process of application. - acquire the awareness of the importance of strategy and management in the use of TES. - acquire the knowledge of the main companies involved in the various aspects of TES (material, envelopes, fluids). - have a critical understanding of the physical principles used in TES. - be able to compare the design, operation and performances of the main types of TES. - be able to choose the relevant TES for a particular application. - be able to highlight the main limitations of a TES. - be able to avoid the usual mistakes encountered in TES. - be able to propose companies providing the various components of TES.
Module contents	1. Overview on Thermal Energy Storage (TES) - TES definitions - TES functionalities - TES basic principles - TES technologies - ES hybridations - ES bottlenecks and current research areas 2. Needs of TES in solar applications - Resource/demand shift management - Thermal protection - Thermal regulation - Production optimisation - Process design optimisation - Process management 3. Available technologies (sensible, latent heat, thermochemical) - Sensible heat based TES, direct mode. - Sensible heat based TES, indirect mode. - Latent heat based TES (organic, inorganic) - Thermochemical based TES 4. Related materials - Low temperature TES materials (sensible heat, latent heat, thermochemical, classifications and properties, characterizations) - High temperature TES materials (sensible heat, latent heat, thermochemical, classifications and properties, characterizations) 5. Heat transfer interfaces and fluids - Envelops for TES units - Insulating materials for TES units - Heat transfer fluids for TES 6. Implementation of TS - TES integration - TES instrumentation - TES charge/discharge assessments 7. Management and strategy of TS - TES management - TES strategy - LTA of TES in Solar Applications 8. Related companies and products - Companies and products for sensible heat based TES - Companies and products for latent heat based TES

		- Companies and products for thermochemical TES - Companies and products for envelopes and connections	
Literaturempfehlungen		F. P. Incropera, D.P. DeWitt (ed.): Fundamentals of Heat and Mass Transfer, ISBN 0471304603. A. V. Da Rosa, Elsevier (ed.): Fundamentals of renewable Energy Processes, 2005, ISBN 0120885107. I. Dincer, M.A. Rosen, Wiley (ed.):Thermal Energy Storage, 2002, ISBN 0471495735. J.A. Duffie, W.A. Beckman: Solar Engineering of Thermal Processes, Wiley ed., 2006, ISBN 100471698679. B. Sorensen: Renewable Energy, Elsevier, 2004, ISBN 0126561532. Gil, A., Medrano, M., Martorell, I., Lazaro, A., Dolado, P., Zalba, B., and Cabeza, L.F.: State of the art on high temperature thermal energy storage for power generation. Part 1-Concepts, materials and modelization, Renew. and Sust. Energy Reviews, 2010, 14, pp. 31-55. Medrano, M., Gil, A., Martorell, I., Potau, X., and Cabeza, L.F.: State of the art on high temperature thermal energy storage for power generation. Part 2-Case studies, Renew. and Sust. Energy Reviews, 14, pp. 56-72.	
Links			
Language of instruction		English	
Duration (semesters)		1 Semester	
Module frequency		jährlich	
Module capacity		unlimited	
Examination	Prüfungszeiten		Type of examination
Final exam of module	End of the Semester		Written exam: 2 hours
Form of instruction	Seminar		
Frequency			

pre365 - Fundamentals

Module label	Fundamentals
Modulkürzel	pre365
Credit points	7.0 KP
Workload	210 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	After the completion of the module the student will - understand the theoretical basis of radiation models to be used in solar engineering processes. - understand the principles and the modelling approaches of combined heat and mass transfer in solar processes. - understand the effect of radiation in a solar process. - understand the radiative heat transfer methods of resolution to be used in solar applications. - understand the various assumptions and computing efficiency of radiation models. - understand the models' limitations to practical uses. - acquire the knowledge of the main radiative properties of materials used in solar processes. - be aware of the important development in radiation measurement. - acquire knowledge of the optical measurement issues. - have a critical understanding of the effect of radiation on fluid flows. - have a critical understanding of radiation modelling in solar processes. - have a critical understanding of the methodology that should be used in a practical situation where radiative heat transfer is to be solved, and coupled with other transfer modes. - be able to compare and evaluate radiation simulation results from different models. - have a critical understanding of optical properties and their influences on radiation heat transfer. - will have a critical understanding of optical measurements.
Module contents	1. Radiative heat transfer - Fundamentals of Thermal Radiation - Radiative Exchange between Surfaces - Radiative properties of opaque surfaces - View factors - Radiative exchange between grey and diffuse surfaces - Equation of Radiative Transfer in Participating Media - Equation of radiative transfer - Formal solutions - Boundary conditions - Radiative Properties of Participating Media - Radiative properties of molecular gases - Radiative properties of particulate media - Radiative Transfer through Participating Media - Collimated irradiation - The Two-Flux method - The method of Discrete Ordinates - The Monte Carlo method - The Rosseland approximation - The Diffusion approximation - High temperature measurements - Pyrometry - Infrared thermography 2. Combined heat and mass - Conduction - Fundamental Equations - Balance equations - Examples - Convection - Fundamental Equations - Forced Convection (resolution of the Couette flow with temperature) - Natural Convection (approximation of Boussinesq) - Adimensionnal equations - CFD softwares
Literaturempfehlungen	Modest M. F.: Radiative Heat Transfer. 2003. Siegel R., Howell J.R.: Thermal Radiation Heat Transfer. 2002. Lesieur: Turbulence in Fluids, Kluwer Academic Publisher, 1997.

		James, Smith and Wolford: Applied numerical methods for digital computation, Harper & Row, New-York.	
Links			
Language of instruction		English	
Duration (semesters)		1 Semester	
Module frequency		jährlich	
Module capacity		unlimited	
Examination	Prüfungszeiten		Type of examination
Final exam of module	Written exam : End of the Semester / end of May Written report : during the semester / February to May		Written exam (50%): 2 hours Written report (50%): extended laboratory report, 10-20 pages
Form of instruction	Seminar		
Frequency			

pre366 - Solar Low Temperature

Module label	Solar Low Temperature
Modulkürzel	pre366
Credit points	7.0 KP
Workload	210 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	At the end of the module the student will - understand the principles of operation, design and methods of low temperature solar energy use: building heating and cooling, microgeneration systems. - be aware of the potentialities of solar resource for energy saving in building - be aware of the solar heating and cooling technologies - understand the different solar collector technologies - understand the thermodynamics of energy conversion systems - be familiar with the utilisation of different numeric tools for heating systems design, performance evaluation and techno-economic viability - have a critical understanding of the physical principles relating to the operation and design of solar collectors. - be able to compare the design and operation of solar heating and/or cooling systems in buildings - will have a critical understanding of the complete system efficiency on the basis of sub-systems efficiency limitation.
Module contents	1. Solar Collectors theory and technologies - The solar resource - Direct and indirect irradiance - Mask effects - Solar collectors theory - Plate collectors - Evacuated collectors - Low concentrated collectors - Solar collectors technologies and application - Design software for implantation in buildings. 2. Solar Conversion (solar heating/cooling, microgeneration) - Thermodynamics optimisation : exergy analysis - Potentialities of low temperature solar energy for cooling - Potentialities of low temperature solar energy for electricity production - Heat driven cooling system theory and technologies - Liquid absorption system - Solid sorption systems - Microgeneration : ORC and Stirling systems
Literaturempfehlungen	B. Sorensen: Renewable Energy. Elsevier, 2004. Richard E. Sonntag , Gordon J. Van Wylen: Applied thermodynamics. ERPI,2004
Links	
Language of instruction	English
Duration (semesters)	1 Semester
Module frequency	jährlich
Module capacity	unlimited

Examination	Prüfungszeiten	Type of examination
Final exam of module	Written exam : End of the Semester / end of May Written report : during the semester / February to May	Written exam (50 %): 2 hours Written report (50%): extended laboratory report, 10-20 pages
Form of instruction	Seminar	
Frequency		

pre367 - Solar High Temperature

Module label	Solar High Temperature
Modulkürzel	pre367
Credit points	12.0 KP
Workload	360 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	At the end of the module the student will - understand the principles of operation, design and methods of production of concentrated solar plants and the principles of thermochemistry and process engineering to produce either gaseous or liquid fuels using concentrated solar energy and resource of C, H, O elements. - be aware of the potentialities of concentrated solar resource for energy vectors production (mechanical, electricity, fuels) - will understand the different solar concentrating systems: linear concentration, point concentration, high concentration systems - understand the thermodynamics of chemical reactions that lead to fuels production from solar heat. - be familiar with the utilisation of different numeric tools for CSP design, performance evaluation and techno-economic viability - have a critical understanding of the physical principles relating to the operation and design of concentrating systems, solar receivers and concentrated solar plants. - be able to compare the design and operation of concentrating systems, solar receivers and concentrated solar plants. - have a critical understanding on the influence of the design and performance of concentrating systems on solar receivers. - have a critical understanding of the thermodynamic limitation of solar fuels production - have a critical understanding of the complete system efficiency on the basis of sub-systems efficiency limitation. - be able to compare and evaluate different chemical pathways with respect to solar energy stored in the chemicals and to CO2 mitigation impact. - have a critical understanding of the principles of solar thermochemical reactor design and modelling. - be able to compare and evaluate various solar thermochemical and thermodynamic processes.
Module contents	1. Solar concentrating systems and receiver - The solar resource for concentrating systems - Introduction to concentration optics - Linear concentration: trough and linear Fresnel - Point concentration: Dish and Tower (Central receiver systems) - High concentration systems: solar furnace and compound parabolic concentrator (CPC) - Selective surfaces for solar receiver - Solar receivers (absorbers) for linear concentrators 2. Solar concentrating systems and receiver - Introduction to Concentrating Solar Power (CSP): various options, plants in operation, industry - Tools for CSP design and performance evaluation - Techno-economics of CSP - Case study: Parabolic trough plant - Case study: Central receiver plant - Case study: Dish-engine plant - Cogeneration systems: electricity and heat, electricity and water 3. Solar fuels - Thermodynamics of chemical reactions - Chemical pathways to hydrogen, methanol and hydrocarbons from water, carbon dioxide and carbonaceous materials - Energy and exergy balances - Energy and material balances when using natural gas, coal and biomass as Carbon resource - Principle of Redox reaction to split H2O and CO2 - Various options for redox reactions - Material and separation issues of the various options - Thermodynamics and kinetics of the various redox reactions - Principles of solar reactors - Material issues in solar reactors - Concentrating systems for high temperature solar thermochemistry

		- Efficiency of a solar thermochemical process - Case study as a function of the reaction temperature - Lab-scale and pilot scale development, state of the art - Solar thermo-chemistry for industry
Literaturempfehlungen		Journal of Solar Energy Engineering Proceedings of SolarPACES Piatkowski N. et al.: Energy and Environmental Science (2011), 4, 73 Abanades S. et al.: Energy (2006) 31, 2469 W. Chueh et al.: Science, (2010) 330, 1797 Schunk L.O. et al.: Chemical Engineering Journal (2009) 150, 502 Maag G. et al.: International Journal of Hydrogen Energy (2010), 35, 13232
Links		
Language of instruction		English
Duration (semesters)		1 Semester
Module frequency		jährlich
Module capacity		unlimited
Examination	Prüfungszeiten	Type of examination
Final exam of module	Written exam: End of the semester / end of May Written reports: during the semester / February to May	Written exam (33%): 2 hours Written report (33%): extended laboratory report, 10 pages Written report (33%): project report, 30 pages
Form of instruction	Seminar	
Frequency		

pre371 - Distributed Generation

Module label	Distributed Generation	
Modulkürzel	pre371	
Credit points	2.0 KP	
Workload	60 h	
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule	
Zuständige Personen		
Prerequisites		
Skills to be acquired in this module	By the end of this module, the student will - be able to manage theoretical aspects related to power distribution, stability and quality The students will: - become familiar with the basic theory and practical knowledge about the electric energy - get basic knowledge on supply guarantee and power quality topics - get basic knowledge on stability issues - know the main effects of the introduction of Renewable Energies into the electric grid - become familiar with the substations principles - get knowledge about the concept of distributed generation and its implications - will be able to demonstrate in-depth knowledge of Power Systems operations and Distributed Generation integration in existing grids - be able to work effectively as professionals and as team members in order to solve technical problems - be able to demonstrate their abilities to communicate effectively in multinational teams	
Module contents	- Introduction to electric grid - Security of supply and grid quality - Stability - Electric circuits analysis - Renewable energy impact on the grid - Laboratory classes (three-phase systems) - Laboratory classes (reactive energy compensation) - Models or patterns of consumption. Response / Demand Management - Basic concepts of power electronics	
Literaturempfehlungen	John J. Grainger, William D. Stevenson: Power System Analysis. McGraw-Hill Inc, 1995. J. Duncan Glover, Mulukutla S. Sarma, and Thomas Overbye: Power System Analysis and design. Cengage Learning, 2008. Theodore Wildi: Electrical Machines, Drives and Power System. Prentice-Hall, 2002. A.J. Pansini: Guide to Electrical Power Distribution Systems. The Fairmont Press Inc, 2005. M.Paz Comech, M. Garcia-Gracia: Tecnología eléctrica. A.A. Bayod; J.L. Bernal; J.A. Dominguez; M.A. García García; A. Llombart; J.M. Yusta: Análisis de circuitos eléctricos I. Colección Textos Docentes, vol. 58. Prensas Universitarias de Zaragoza.	
Links		
Language of instruction	English	
Duration (semesters)	1 Semester	
Module frequency	jährlich	
Module capacity	unlimited	
Examination	Prüfungszeiten	Type of examination
Final exam of module	After end of lectures of module	Written exam (95%): 2 hours Subject's work (5%): approx. 4 hours (Subject's work refers to the different assignments that students are asked to finish after a preliminary session during the lessons)
Form of instruction	Seminar	
Frequency		

pre372 - Generation and Storing Technologies

Module label	Generation and Storing Technologies
Modulkürzel	pre372
Credit points	4.5 KP
Workload	135 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	By the end of this subject, students should be able to display a clear understanding of the state of the art of RE power generation technologies, the theoretical aspects of storage technologies and the impact of electric vehicles in the electric grid. The student will get a suitable knowledge about the following topics: - Distributed Generation main concepts - New generation technologies - Wind power generation - Biomass power - Hydraulic Power - Storage - Electric vehicle regarding grid integration Engineering analysis: Graduates will be able to demonstrate a clear understanding of the state of the art of RE power generation technologies and related aspects as storage or impact in the electric grid. Transferable skills: Graduates will be able to work effectively as a professional and as team member in the resolution of technical problems. Also, graduates will demonstrate their abilities to communicate effectively in multinational groups.
Module contents	1. Basics aspects of Distributed Generation - Challenges of the SEP operation due to the high penetration of RES - Challenges and technological trends in the renewable energy grid integration - Advantages and disadvantages of distributed generation - Optimization of the integration of distributed generation - Marine and offshore technology generation and market - Visit to PV system facility - Applications of hydrogen and visit to the Hydrogen Foundation - Visit to a hydroelectric plant - Electric Vehicle - Wind prediction techniques 2. Storage - State of the art storage - Batteries - Flywheel - Storage systems based on ultra-capacitors
Literaturempfehlungen	A. Ter-Gazarian: Energy Storage for Power Systems. IEE Energy, No 6. Felix A. Farret and M. Godoy Simoes: Integration of Alternative Sources of Energy. John Wiley and Sons, 2006. Ann-Marie Borbely, Jan F. Kreider: Distributed Generation. CRC Press, 2001.
Links	
Language of instruction	English
Duration (semesters)	1 Semester
Module frequency	jährlich
Module capacity	unlimited

Examination	Prüfungszeiten	Type of examination
Final exam of module	After end of lectures of module	Written exam (42.5%): 2 hours Subject's work (7.5%): approx. 4 hours (Subject's work refers to the different assignments that students are asked to finish after a preliminary session during the lessons) Presentation (50%): 20 minutes (developed topic)

Form of instruction	Seminar
Frequency	

pre373 - Control Techniques and Renewable Energy Integration Systems

Module label	Control Techniques and Renewable Energy Integration Systems
Modulkürzel	pre373
Credit points	5.5 KP
Workload	165 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	By the end of this module, students should be able to manage the theoretical and practical aspects related to power electronics, with an emphasis in the analysis of the operation of specific devices used to integrate RE. They should also be able to evaluate the requirements, design and optimise Micro Grids. At the completion of this module, the student will: - Become familiar with the AC/DC Drives control systems (multilevel converters, PWM, etc…) - Get basic knowledge on the technological aspects of power electronic systems connection - Get knowledge about reactive power compensation - Be introduced to FACTS Technology Engineering analysis: Graduates will be able to formulate and solve engineering problems related to the control of power systems connected to the grid. Also, the will be able to design and optimise Micro Grids. Investigations: Graduates will be able to evaluate the requirements to implement Micro Grids. Transferable skills: Graduates will be able to work effectively as professionals and as team members to solve technical problems related to the integration of RE in electric grids. Also, graduates will demonstrate their abilities to communicate effectively in multinational teams.
Module contents	1. Control of AC/DC drives - Necessity of power electronics: solar and wind generation, storage, dip and reactive power compensation, DC transport… - Modelling and simulation of power electronics systems - Conversion DC/DC (Solar): topology, operation and current control - Vectorial modelling of three phase systems - Control of permanent magnets wind turbines - Conversion DC/AC three phase - Control of active and reactive power of three phase systems connected to grid - Dip and interruptions compensation: DVR - Characterization techniques: harmonics, THD, power factor… - Overview of other power systems 2. Active network devices and control - Control system for small wind turbines - Power inverter design - Microgrids - Theory and operation principles of FACTS - FACTS implementation and technology (Series / Shunt compensation) - Applications and simulation of power electronics systems using PSCAD/EMTDC - Modelling of thyristor-based static Var compensator - Modelling of GTO-Based STATCOM -Modelling of VSC-Based HVD link - Modelling and performance of SSCC in wind energy application
Literaturempfehlungen	N.G. Hingorani; L. Gyugyi: Understanding FACTS: Concepts and Technology of Flexible AC. Transmission Systems. John Wiley and Sons, 1999. E. Acha; C.R. Fuerte-Esquivel; H. Ambriz-Perez; C. Angeles-Camacho: FACTS, Modelling and Simulation in Power Networks. John Wiley and Sons, 2004. N. Mohan; T.M. Undeland; W.P. Robbins: Power Electronics, Converters, Applications and Design. John Wiley and Sons, 1995. Muhammad H. Rashid: Power Electronics Handbook. Academic Press, 2001. Remus Teodorescu, Marco Liserre, Pedro Rodriguez: Grid Converters for Photovoltaic and Wind Power Systems. IEEE- Wiley and Sons Publications, 2011.
Links	
Language of instruction	English
Duration (semesters)	1 Semester

Module frequency	jährlich	
Module capacity	unlimited	
Examination	Prüfungszeiten	Type of examination
Final exam of module	After end of lectures of module	Written exam (40%): 2 hours Subject's work (20%): approx. 8 hours (Subject's work refers to the different assignments that students are asked to finish after a preliminary session during the lessons) Presentation (40%): 20 minutes (developed topic)
Form of instruction	Seminar	
Frequency		

pre374 - Power Grid Analysis and Studies

Module label	Power Grid Analysis and Studies
Modulkürzel	pre374
Credit points	6.0 KP
Workload	180 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	By the end of this module students should be able to acquire relevant data to evaluate grid power quality, to model permanent and dynamic transient regimes of electric grid elements and to plan and optimise grid design. Specifically, the student will - be able to perform different studies (permanent, dynamic or transitional regimes) to undertake in electric grids to ensure correct planning and operation - get basic knowledge on grid modelling (static and dynamic) - be able to perform stability studies - get to know different aspects about power supply quality - be able to perform an optimal sizing of renewable energies installations Engineering analysis: Graduates will be able to formulate and solve engineering problems related to Power Supply Quality. Investigations: Graduates will be able to acquire relevant data to evaluate grid power quality. Engineering design: Graduates will be able to model permanent and dynamic transient regimes of electric grid elements, also to plan and optimise grid design. Transferable skills: Graduates will be able to work effectively as a professional and as team member in the resolution of technical problems related to integration of RE in electric grids. Also, graduates will demonstrate their abilities to communicate effectively in multinational groups.
Module contents	1. Electric system modelling - Introduction to the modelling and simulation of electric systems - Per unit system - Permanent regime simulation studies: load flows, short-circuits, sequence networks - Transient regime modelling: lines, transformer, SEP stability, generation - Modelado de sistemas eléctricos en régimen transitorio. - RE integration analysis 2. Quality of supply - Wind and solar farms verification procedures - Grid Codes and dynamic models for different wind turbines - Variable frequency drive - Slow voltage variations - Voltage fluctuations Flicker - Voids voltage and short cuts - Voltage pulses - Harmonic distortion - Voltage Imbalances - Network quality and renewable energy - Power quality analysers
Literaturempfehlungen	John J. Grainger, William D. Stevenson: Power System Analysis. McGraw-Hill Inc, 1995. N.D. Tleis: Power Systems Modelling and Fault Analysis: Theory and Practice. Elsevier Ltd, 2008.
Links	
Language of instruction	English
Duration (semesters)	1 Semester
Module frequency	jährlich
Module capacity	unlimited

Examination	Prüfungszeiten	Type of examination
Final exam of module	After end of lectures of module	Written exam (50%): 2 hours Subject's work (10%): approx. 8 hours (Subject's work refers to the different assignments that students are asked to finish after a preliminary session during the lessons)

Examination	Prüfungszeiten	Type of examination
		Presentation (40%): 20 minutes (developed topic)
Form of instruction	Seminar	
Frequency		

pre375 - Smart Grids

Module label		Smart Grids	
Modulkürzel		pre375	
Credit points		4.5 KP	
Workload		135 h	
Verwendbarkeit des Moduls		• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule	
Zuständige Personen			
Prerequisites			
Skills to be acquired in this module		By the end of this module, students should be able to program and protect smart grids. Student will get a suitable knowledge on: - smart grid concept and development - protection system in electrical power systems - telecommunication infrastructure in smart grids Engineering design: Graduates will be able to design engineering solutions to the challenge of programming smart-grids. They will be able to do the complex task of coordinating protective devices for RE, integrate mini and micro generation in distribution grids or plan and optimise primary-secondary distribution systems. Transferable skills: Graduates will be able to work effectively as a professional and as team member in the resolution of technical problems related to integration of RE in electric grids. Also, graduates will demonstrate their abilities to communicate effectively in multinational groups.	
Module contents		1. Programming of intelligent networks - Smart Grids from the point of view of the network operator (Demand Management, Electric Vehicle, Storage...) - Operation and network planning with quality criteria distribution - Optimization Techniques - Practice microgrids 2. Protections - Introduction - Overcurrent protection - Distance protection - Differential protection - Protection coordination - Problematic of distributed generation 3. Smart Grids - IEC 61850 communications - Visit to Red Eléctrica de España control center - Visit to UFD facilities: Smart grids projects - PLC communications: Malaga Smart city experience - Visit to ERZ control center: smart meters	
Literaturempfehlungen		Power Systems Protection, Power Quality, Substation Automation. IDC TechBooks, 1994. IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems. IEEE Inc, 2001. Q.H. Wu; Z. Lu; T.Y. Ji: Protective Relaying of Power Systems Using Math. Morphology. Springer, 2009. C.R. Mason: The Art and Science of Protective Relaying. GE Inc. P.I. Morreale, K. Terplan: Telecommunication—Handbooks, manuals, etc. CRC Press, 2000.	
Links			
Language of instruction		English	
Duration (semesters)		1 Semester	
Module frequency		jährlich	
Module capacity		unlimited	
Examination	Prüfungszeiten		Type of examination
Final exam of module	After end of lectures of module		Written exam (50%): 2 hours Subject's work (10%): approx. 4 hours (Subject's work refers to the different assignments that students are asked to finish after a preliminary session during the lessons) Presentation (40%): 20 minutes (developed topic)
Form of instruction	Seminar		

Frequency

pre376 - Standards and Electric Markets

Module label	Standards and Electric Markets	
Modulkürzel	pre376	
Credit points	2.5 KP	
Workload	75 h	
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule	
Zuständige Personen		
Prerequisites		
Skills to be acquired in this module	By the end of this module, students should be able to display a clear understanding of the different laws and economic regulations ruling distributed generation in liberalised electric markets. Also, they should be able to identify boundaries and opportunities in those markets. At the completion of this module, the student will: - become familiar with the basic rules of electric markets - get know the standards for RE - know the smart grid installations from the economical point of view Engineering practice: Graduates will possess a comprehensive understanding of the structure and regulations of local and international electric markets. The economics of distributed generation systems. The state of the art in standards and regulations ruling distributed generation in liberalised electric markets. Transferable skills: Graduates will be able to work effectively as a professional and team member in the resolution of technical problems related to integration of RE in electric grids. Also, graduates will demonstrate their abilities to communicate effectively with the engineering community in national and international contexts. They are able to demonstrate awareness of the legal issues and responsibilities of the engineering practice.	
Module contents	- The electricity sector: structures and models - Cost-benefit analysis of investment in RES - Calculation of tariffs considering quality costs - Socio-economic impact of Smart Grids - Impact of high penetration of RES in the electricity market - Specific regulations for renewable energy	
Literaturempfehlungen	The Power to Choose: Demand Response in Liberalised Electricity Markets. OECD/IEA, 2003.	
Links		
Language of instruction	English	
Duration (semesters)	1 Semester	
Module frequency	jährlich	
Module capacity	unlimited	
Examination	Prüfungszeiten	Type of examination
Final exam of module	After end of lectures of module	Written exam (50%): 2 hours Presentation (50%): 20 minutes (developed topic)
Form of instruction	Seminar	
Frequency		

pre377 - Project

Module label		Project	
Modulkürzel		pre377	
Credit points		5.0 KP	
Workload		150 h	
Verwendbarkeit des Moduls		• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule	
Zuständige Personen			
Prerequisites			
Skills to be acquired in this module		Investigations: Graduates will be able to search and organise the required information for the report. Transferable skills: To evaluate students learning process through the development of a subject related to any of the modules in the specialization. Graduates will demonstrate their ability to investigate and recognise the need for lifelong learning.	
Module contents		Students develop a project on any subject, related to any of the modules in the specialization. The issue is approved by a professor who directs and guides the student. Any module coordinator can be director of the project. For evaluation, the student submits a report of the work.	
Literaturempfehlungen		Recommended literature of other modules	
Links			
Language of instruction		English	
Duration (semesters)		1 Semester	
Module frequency		jährlich	
Module capacity		unlimited	
Examination	Prüfungszeiten		Type of examination
Final exam of module	After end of modules		Written report
Form of instruction	Seminar		
Frequency			

pre381 - Processes, models & modelling

Module label		Processes, models & modelling	
Modulkürzel		pre381	
Credit points		10.0 KP	
Workload		300 h	
Verwendbarkeit des Moduls		• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule	
Zuständige Personen			
Prerequisites			
Skills to be acquired in this module			
Module contents			
Literaturempfehlungen			
Links			
Languages of instruction			
Duration (semesters)		1 Semester	
Module frequency			
Module capacity		unlimited	
Type of module		je nach Studiengang Pflicht oder Wahlpflicht	
Module level		---	
Examination	Prüfungszeiten		Type of examination
Final exam of module			KL
Form of instruction	Seminar		
Frequency			

pre382 - Biochemical conversion

Module label		Biochemical conversion	
Modulkürzel		pre382	
Credit points		10.0 KP	
Workload		300 h	
Verwendbarkeit des Moduls		• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule	
Zuständige Personen			
Prerequisites			
Skills to be acquired in this module			
Module contents			
Literaturempfehlungen			
Links			
Languages of instruction			
Duration (semesters)		1 Semester	
Module frequency			
Module capacity		unlimited	
Type of module		je nach Studiengang Pflicht oder Wahlpflicht	
Module level		---	
Examination	Prüfungszeiten		Type of examination
Final exam of module			KL
Form of instruction	Seminar		
Frequency			

pre383 - Thermochemical conversion

Module label		Thermochemical conversion	
Modulkürzel		pre383	
Credit points		5.0 KP	
Workload		150 h	
Verwendbarkeit des Moduls		• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule	
Zuständige Personen			
Prerequisites			
Skills to be acquired in this module			
Module contents			
Literaturempfehlungen			
Links			
Languages of instruction			
Duration (semesters)		1 Semester	
Module frequency			
Module capacity		unlimited	
Type of module		Wahlpflicht / Elective	
Module level		MM (Mastermodul / Master module)	
Examination	Prüfungszeiten		Type of examination
Final exam of module			KL
Form of instruction	Seminar		
Frequency			

pre384 - New Business

Module label		New Business	
Modulkürzel		pre384	
Credit points		5.0 KP	
Workload		150 h	
Verwendbarkeit des Moduls		• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule	
Zuständige Personen			
Prerequisites			
Skills to be acquired in this module			
Module contents			
Literaturempfehlungen			
Links			
Languages of instruction			
Duration (semesters)		1 Semester	
Module frequency			
Module capacity		unlimited	
Type of module		Wahlpflicht / Elective	
Module level		MM (Mastermodul / Master module)	
Examination	Prüfungszeiten		Type of examination
Final exam of module			3 Prüfungsleistungen: Referat 1 (Präsentation max. 20 min + Bericht max. 15 Seiten; Gewicht: 20%) Referat 2 (Präsentation max. 20 min + Bericht max. 15 Seiten; Gewicht: 40%) Präsentation (max. 20 min; Gewicht: 40%)
Form of instruction	Seminar		
Frequency			

pre355 - Development and Implementation

Module label	Development and Implementation
Modulkürzel	pre355
Credit points	10.0 KP
Workload	300 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	
Module contents	
Literaturempfehlungen	
Links	
Languages of instruction	German, English
Duration (semesters)	1 Semester
Module frequency	
Module capacity	unlimited
Type of module	je nach Studiengang Pflicht oder Wahlpflicht
Module level	---

Examination	Prüfungszeiten	Type of examination
Final exam of module		2 Prüfungsleistungen: Seminararbeit (ca. 3000 Wörter) und Referat (10min Präsentation + 3000 Wörter Bericht). Gewicht je 50%.

Form of instruction	Comment	SWS	Frequency	Workload of compulsory attendance
Lecture		2	SoSe und WiSe	28
Exercises		4	SoSe und WiSe	56
Präsenzzeit Modul insgesamt				84 h

pre385 - Sustainable Fuel Supply Chains

Module label	Sustainable Fuel Supply Chains
Modulkürzel	pre385
Credit points	10.0 KP
Workload	300 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	
Module contents	
Literaturempfehlungen	
Links	
Languages of instruction	German, English
Duration (semesters)	1 Semester
Module frequency	
Module capacity	unlimited
Type of module	Wahlpflicht / Elective
Module level	MM (Mastermodul / Master module)

Examination	Prüfungszeiten	Type of examination
Final exam of module		5 Prüfungsleistungen: 2 Klausuren zu je (1,5h, Gewicht: 20%), 3 Referate zu je (Präsentation max. 20 min + Bericht max. 15 Seiten, Gewicht: 20%)

Form of instruction	Comment	SWS	Frequency	Workload of compulsory attendance
Lecture		2	SoSe und WiSe	28
Exercises		4	SoSe und WiSe	56
Präsenzzeit Modul insgesamt				84 h

pre386 - Bio Energy Conversion

Module label	Bio Energy Conversion
Modulkürzel	pre386
Credit points	10.0 KP
Workload	300 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	
Module contents	
Literaturempfehlungen	
Links	
Languages of instruction	German, English
Duration (semesters)	1 Semester
Module frequency	
Module capacity	unlimited
Type of module	Wahlpflicht / Elective
Module level	MM (Mastermodul / Master module)

Examination	Prüfungszeiten	Type of examination
Final exam of module		4 Prüfungsleistungen: Klausur 1 (1,5h, Gewicht: 20%), Klausur 2 (1,5h, Gewicht: 30%), Referat 1 (Präsentation max. 20 min + Bericht max. 15 Seiten, Gewicht: 20%) und Fachpraktische Übung (Gewicht: 30%)

Form of instruction	Comment	SWS	Frequency	Workload of compulsory attendance
Lecture		2	SoSe und WiSe	28
Exercises		4	SoSe und WiSe	56
Präsenzzeit Modul insgesamt				84 h

pre387 - Power-to-Hydrogen

Module label	Power-to-Hydrogen
Modulkürzel	pre387
Credit points	5.0 KP
Workload	150 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	
Module contents	
Literaturempfehlungen	
Links	
Languages of instruction	German, English
Duration (semesters)	1 Semester
Module frequency	
Module capacity	unlimited
Type of module	Wahlpflicht / Elective
Module level	MM (Mastermodul / Master module)

Examination	Prüfungszeiten	Type of examination
Final exam of module		2 Prüfungsleistungen: Präsentation (max. 20 min, Gewicht 40%), Fachpraktische Übung (Gewicht 60%)

Form of instruction	Comment	SWS	Frequency	Workload of compulsory attendance
Lecture		2	SoSe und WiSe	28
Exercises		2	SoSe und WiSe	28
Präsenzzeit Modul insgesamt				56 h

pre400 - Fundamentals for Renewable Energy

Module label	Fundamentals for Renewable Energy
Modulkürzel	pre400
Credit points	12.0 KP
Workload	360 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	• Agert, Carsten (Prüfungsberechtigt) • Günther, Andreas (Prüfungsberechtigt) • Holtorf, Hans-Gerhard (Prüfungsberechtigt) • Jimenez Martinez, Cuauhtemoc Adrian (Prüfungsberechtigt) • Knecht, Robin (Prüfungsberechtigt) • Torio, Herena (Prüfungsberechtigt) • Malz, Simone (Prüfungsberechtigt) • Ziethe, Paul (Prüfungsberechtigt)
Prerequisites	
Skills to be acquired in this module	
Module contents	
Literaturempfehlungen	
Links	
Languages of instruction	German, English
Duration (semesters)	1 Semester
Module frequency	
Module capacity	unlimited
Type of module	Wahlpflicht / Elective
Module level	MM (Mastermodul / Master module)

Examination	Prüfungszeiten	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%)

Form of instruction	Comment	SWS	Frequency	Workload of compulsory attendance
Lecture		2	SoSe und WiSe	28
Exercises		2	SoSe und WiSe	28
Werkstatt/Labor		4	SoSe und WiSe	56
Präsenzzeit Modul insgesamt				112 h

pre405 - Energy Resources and Systems

Module label		Energy Resources and Systems	
Modulkürzel		pre405	
Credit points		6.0 KP	
Workload		180 h	
Verwendbarkeit des Moduls		• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule	
Zuständige Personen		• Torio, Herena (Prüfungsberechtigt)	
Prerequisites			
Skills to be acquired in this module			
Module contents			
Literaturempfehlungen			
Links			
Languages of instruction		German, English	
Duration (semesters)		1 Semester	
Module frequency			
Module capacity		unlimited	
Type of module		Wahlpflicht / Elective	
Module level		MM (Mastermodul / Master module)	
Examination	Prüfungszeiten		Type of examination
Final exam of module			1 Prüfungsleistung: Klausur (2h)
Form of instruction	Lecture		
SWS	4		
Frequency	SoSe und WiSe		

pre410 - Renewable Energy Technologies I

Module label	Renewable Energy Technologies I
Modulkürzel	pre410
Credit points	12.0 KP
Workload	360 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	• Hölling, Michael (Prüfungsberechtigt) • Holtorf, Hans-Gerhard (Prüfungsberechtigt) • Torio, Herena (Prüfungsberechtigt) • Wark, Michael (Prüfungsberechtigt) • Pehlken, Alexandra (Prüfungsberechtigt) • Steinberger-Wilckens, Robert (Prüfungsberechtigt) • Knipper, Martin (Prüfungsberechtigt) • 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:

- critically evaluate and compare three major Renewable Energy conversion processes and technologies: photovoltaics, wind energy and one out of the following three: 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

Depending on the selected area, students should be able to:

- Photovoltaics
  - understand, describe and compare major technologies for photovoltaic solar energy usecritically appraise and assess various technologies for PV 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
- Basics of Wind Energy
  - Understand the physical principal of wind energy conversion
  - Understand wind turbine aerodynamics
  - Critically evaluate and describe basic characteristics and functioning of wind energy converters
- Fuel Cells & Energy Storage
  - Understand the operation principles and main variables influencing different fuel cell technologies
  - Understand principles and variables governing the behaviour of electrical storage systems
  - Critically evaluate and describe electrochemical storage systems with a focus on batteries as well as hydrogen storage systems (electrolyser, gas storage and fuel cells)
- Solar Thermal Energy
  - understand, describe and compare major technologies for solar thermal energy use
  - analyse various system components and their interconnections within a solar energy system.
  - critically appraise and assess various technologies for solar thermal 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
- Biomass Energy
  - understand the basic chemical background of bioenergy-related

materials, systems and processes
    - understand different technology concepts for bioenergy usage
    - Understand the links between biomass sources and other production processes (different substrats, different deployment processes)
    - Get to know main economical and legal constraints for biomass energy use
- Hydro & Marine Power
    - Understand main technologies for hydro and marine power use (different turbine types, their different sizes and uses as well as main variables influencing the performance of the systems in each case
    - Understand principles and methods to assess the hydro and marine-power resource potential of a site
    - Appraise the links between different components in a water-based energy system to assess its overall performance
    - Identify critical points in the implementation and use of such 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 lies on the scientific principles and the technical description of the components. Main aspects of the integration of components to form energy supply systems are also regarded.

Photovoltaics (Lecture - 90 h workload)

Physics of PV:

- Basic and most important properties of solar radiation related to photovoltaic
- 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 (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 & Marine 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

Literaturempfehlungen

Suggested reading:

Solar Energy PV

- 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
- Markvart, Tom and Castaner, Luis, 2003: Practical Handbook of Photovoltaics, Fundamentals and Applications, Elsevier Science
- Nelson, Jenny, 2003: The Physics of Solar Cells (Properties of Semiconductor Materials), Imperial College Press.
- Stuart R. Wenham, Martin A. Green, Muriel E. Watt& Richard Corkish (Edit.), 2007: Applied Photovoltaics, Earthscan Publications Ltd.;
- Twidell, John & Weir, Toni, 2005: Renewable Energy Resources Taylor & Francis.

Basics of Wind Energy

- T. Burton et. al.: Wind Energy Handbook. John Wiley, New York, 2nd ed., 2011
- R. Gasch, J. Twele: Wind Power Plants. Springer, 2nd ed., 2011

Fuel Cells & Energy Storage

- Larminie/Dicks: Fuel Cells Systems Explained, 2000, (Wiley, 2000, ISBN 0-471-49026-1)
- EG&G Services, Parsons Inc.: Fuel Cell Handbook, (DE-AM26-99FT40575, 7th Edition, 2005; www.fuelcells.org/fchandbook.pdf)
- G. Hoogers (Ed.): Fuel Cell Technology Handbook, (CRC Press, Boca

Raton/London, 2003, ISBN 0-8493-0877-1)
- C.-J. Winter/J. Nitsch: Hydrogen as an Energy Carrier (Springer-Verlag, Heidelberg/N.Y., 1985, ISBN 0-387-18896-7/3-540-18896-7)
- O'Hayre/Cha/Colella/Prinz: Fuel Cell Fundamentals, (Wiley, 2009, 2nd ed., IBSN 978-0-470-25843-9)
- C.H. Hamann, A. Hammett, W. Vielstich, Electrochemistry, 2nd Ed. Wiley, Weinheim 2007
- D. Pletcher, A First Course in Electrode Processes. The Electrochemical Consultancy, 1991.
- A.J. Bard, L.R. Faulkner, Electrochemical Methods, Fundamentals and Applications. 2. Ed., Wiley, 2001.
- M. Winter, R.J. Brodd; What are Batteries, Fuel Cells and Supercapacitors? in Chem. Rev. 2004, Vol. 104, pp. 4245-4269
- A.J. Bard, G. Inzelt, F. Scholz (Eds.) Electrochemical Dictionary. 2. Aufl. Springer, Berlin 2012 (Available as an eBook, very good explanation in English)
- Fischer, W. (1996). Stationary lead-acid batteries - an introductory handbook. Brilon, Germany: Hoppecke.

Biomass Energy

- R. Schlögl (Ed.), Chemical Energy Storage, De Gruyter, 2013, ISBN: 978-3-11-026407-4, Chapter 2, Pages 59-133.
- D.L. Klass. Biomass for renewable energy, fuels, and chemicals, Chapter 4 Virgin Biomass Production, p. 91ff
- Food and Agriculture Organization of the UN (FAO) http://www.fao.org
- IEA Energy Technology Essentials - Biomass for Power Generation and CHP. http://www.iea.org/techno/essentials3.pdf
- R.A. Houghton, Forest Hall, and Scott J. Goetz. Importance of biomass in the global carbon cycle J. Geophys. Res., 114, 2009
- Schlögl, Robert (2013). Chemical energy storage (Elektronische Ressource] ed.). Berlin [u.a.]: De Gruyter.
- Twidell & Weir. Renewable Energy Resources, Chapter 10, http://www.4shared.com/document/HpYwRDPy/Renewable_Energy_Resources_2nd.html
- Wheildon's 2013, http://www.wheildons.co.uk/wp-content/uploads/2013/07/carbon-neutral.jpg
- Waste-to-Energy Research and Technology Council (WtERT), 2009, http://www.wtert.eu/default.asp?Menue=13&ShowDok=12#Hydrolysis

Solar Thermal

- DGS, (2010) Planning and installing solar thermal systems, a guide for installers, architects and engineers, 2nd ed.
- Duffie JA, Beckman WA (2013) Solar engineering of thermal processes: Wiley.
- Kasper, B., & Antony, F. (2004). Solarthermische Anlagen.

Hydro Power

- Charlier R.H., (2009) Ocean Energy: Tide and Tidal Power.
- Chtrakar P (2005) Micro-hydropower design aids manual: Small Hydropower Promotion Project, Mini Grid Support Programme. 107p.
- Croockewit J (2004) Handbook for developing micro hydro in British Columbia: BChydro. 69 p.
- Giesecke J, Heimerl S, Mosonyi E (2014) Wasserkraftanlagen: Springer Vieweg. XXVI, 940 p.
- Inversin AR (1986) Micro-hydropower sourcebook: NRECA International Foundation.
- Meder K (2011) Environment Assessment and Watershed Action Planning related to GIZ ECO MHP Projects: Field Manual. GIZ. 24 p.
- Pelikan B (2004) Guide on how to develop a small hydropower plant. European Small Hydropower Association ESHA. 151 p.
- Penche C (1988) Layman's handbook on how to develop a small hydro site; Commission E, editor.
- Rodriguez L, Sánchez T (2011) Designing and building mini and micro hydropower schemes - a practical guide; Action P, editor: Practical Action Publishing Ltd. xxii, 359 p.

Links	
Language of instruction	English
Duration (semesters)	1 Semester

Module frequency	Winter semester
Module capacity	unlimited
Reference text	
Type of module	Pflicht / Mandatory
Module level	MM (Mastermodul / Master module)
Teaching/Learning method	Lectures, Seminars, Exercises
Previous knowledge	Helpful previous knowledge: Chemistry, Black Body Radiation, Semiconductor Physics, Fluid Dynamics

Examination	Prüfungszeiten	Type of examination
Final exam of module	Before the end of the lecture period	4 Exams (weight 25% each): Written exam or Paper with Presentation

Form of instruction	Comment	SWS	Frequency	Workload of compulsory attendance
Lecture		2	SoSe und WiSe	28
Exercises		4	SoSe und WiSe	56
Präsenzzeit Modul insgesamt				84 h

pre420 - Fundamentals

Module label	Fundamentals
Modulkürzel	pre420
Credit points	6.0 KP
Workload	180 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	
Module contents	
Literaturempfehlungen	
Links	
Languages of instruction	German, English
Duration (semesters)	1 Semester
Module frequency	
Module capacity	unlimited
Type of module	Wahlpflicht / Elective
Module level	MM (Mastermodul / Master module)

Examination	Prüfungszeiten	Type of examination
Final exam of module		2 Prüfungsleistungen: Klausur (2h, Gewicht: 50%) und fachpraktische Übung (Versuchsprotokoll 10-20 Seiten, Gewicht: 50%).

Form of instruction	Comment	SWS	Frequency	Workload of compulsory attendance
Lecture		2	WiSe	28
Exercises		2	SoSe und WiSe	28
Präsenzzeit Modul insgesamt				56 h

pre421 - Simulation and System Optimization

Module label	Simulation and System Optimization
Modulkürzel	pre421
Credit points	6.0 KP
Workload	180 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	
Module contents	
Literaturempfehlungen	
Links	
Languages of instruction	German, English
Duration (semesters)	1 Semester
Module frequency	
Module capacity	unlimited
Type of module	Wahlpflicht / Elective
Module level	MM (Mastermodul / Master module)

Examination	Prüfungszeiten	Type of examination
Final exam of module		2 Prüfungsleistungen: Seminararbeit (20 Seiten, Gewicht: 50%) und fachpraktische Übung (Versuchsprotokoll 10 Seiten, Gewicht: 50%).

Form of instruction	Comment	SWS	Frequency	Workload of compulsory attendance
Lecture		2	SoSe und WiSe	28
Exercises		2	SoSe und WiSe	28
Präsenzzeit Modul insgesamt				56 h

pre422 - Energy

Module label	Energy
Modulkürzel	pre422
Credit points	6.0 KP
Workload	180 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	
Module contents	
Literaturempfehlungen	
Links	
Languages of instruction	German, English
Duration (semesters)	1 Semester
Module frequency	
Module capacity	unlimited
Type of module	Wahlpflicht / Elective
Module level	MM (Mastermodul / Master module)

Examination	Prüfungszeiten	Type of examination
Final exam of module		3 Prüfungsleistungen: Klausur (3h) und fachpraktische Übung (Versuchsprotokoll 5 Seiten) und Seminararbeit (20 Seiten). Alle Prüfungsleistungen werden zu je 1/3 gewichtet.

Form of instruction	Comment	SWS	Frequency	Workload of compulsory attendance
Lecture		2	SoSe und WiSe	28
Exercises		2	SoSe und WiSe	28
Präsenzzeit Modul insgesamt				56 h

pre423 - Materials

Module label		Materials	
Modulkürzel		pre423	
Credit points		6.0 KP	
Workload		180 h	
Verwendbarkeit des Moduls		• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule	
Zuständige Personen			
Prerequisites			
Skills to be acquired in this module			
Module contents			
Literaturempfehlungen			
Links			
Languages of instruction		German, English	
Duration (semesters)		1 Semester	
Module frequency			
Module capacity		unlimited	
Type of module		Wahlpflicht / Elective	
Module level		MM (Mastermodul / Master module)	
Examination	Prüfungszeiten		Type of examination
Final exam of module			1 Prüfungsleistung: Klausur (2h)
Form of instruction	Lecture		
SWS	4		
Frequency	SoSe und WiSe		

pre424 - Project, case study and innovation

Module label	Project, case study and innovation
Modulkürzel	pre424
Credit points	6.0 KP
Workload	180 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	
Module contents	
Literaturempfehlungen	
Links	
Languages of instruction	German, English
Duration (semesters)	1 Semester
Module frequency	
Module capacity	unlimited
Type of module	Wahlpflicht / Elective
Module level	MM (Mastermodul / Master module)

Examination	Prüfungszeiten	Type of examination
Final exam of module		2 Prüfungsleistungen: Klausur (2h, Gewicht: 1/3) und Hausarbeit (30 Seiten, Gewicht: 2/3).

Form of instruction	Comment	SWS	Frequency	Workload of compulsory attendance
Lecture		2	SoSe und WiSe	28
Seminar		2	SoSe und WiSe	28
Präsenzzeit Modul insgesamt				56 h

pre430 - Introduction to Electric Power Systems and power electronics

Module label		Introduction to Electric Power Systems and power electronics	
Modulkürzel		pre430	
Credit points		3.0 KP	
Workload		90 h	
Verwendbarkeit des Moduls		• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule	
Zuständige Personen			
Prerequisites			
Skills to be acquired in this module			
Module contents			
Literaturempfehlungen			
Links			
Languages of instruction		German, English	
Duration (semesters)		1 Semester	
Module frequency			
Module capacity		unlimited	
Type of module		Wahlpflicht / Elective	
Module level		MM (Mastermodul / Master module)	
Examination	Prüfungszeiten		Type of examination
Final exam of module			2 Prüfungsleistungen: Klausur (2h, Gewicht: 95%), fachpraktische Übung (Übungsaufgabe, Gewicht: 5%)
Form of instruction	Vorlesung und Übung		
SWS	2		
Frequency	SoSe und WiSe		

pre431 - Distributed energy resources (DER)

Module label	Distributed energy resources (DER)
Modulkürzel	pre431
Credit points	6.1 KP
Workload	183 h
Verwendbarkeit des Moduls	• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule
Zuständige Personen	
Prerequisites	
Skills to be acquired in this module	
Module contents	
Literaturempfehlungen	
Links	
Languages of instruction	German, English
Duration (semesters)	1 Semester
Module frequency	
Module capacity	unlimited
Type of module	Wahlpflicht / Elective
Module level	MM (Mastermodul / Master module)

Examination	Prüfungszeiten	Type of examination
Final exam of module		3 Prüfungsleistungen: Klausur (2h, Gewicht: 42,5%), Präsentation (20min + 10min Diskussion, Gewicht: 50%) und fachpraktische Übung (Übungsaufgabe, Gewicht: 7,5%)

Form of instruction	Vorlesung und Übung
SWS	4
Frequency	SoSe und WiSe

pre432 - Renewable Energy Integration

Module label		Renewable Energy Integration	
Modulkürzel		pre432	
Credit points		5.6 KP	
Workload		168 h	
Verwendbarkeit des Moduls		• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule	
Zuständige Personen			
Prerequisites			
Skills to be acquired in this module			
Module contents			
Literaturempfehlungen			
Links			
Languages of instruction		German, English	
Duration (semesters)		1 Semester	
Module frequency			
Module capacity		unlimited	
Type of module		Wahlpflicht / Elective	
Module level		MM (Mastermodul / Master module)	
Examination	Prüfungszeiten		Type of examination
Final exam of module			3 Prüfungsleistungen: Klausur (2h, Gewicht: 40%), Präsentation (20min + 10min Diskussion, Gewicht: 40%) und fachpraktische Übung (Übungsaufgabe, Gewicht: 20%)
Form of instruction	Vorlesung und Übung		
SWS	4		
Frequency	SoSe und WiSe		

pre433 - DER Impact on EPS

Module label		DER Impact on EPS	
Modulkürzel		pre433	
Credit points		5.2 KP	
Workload		156 h	
Verwendbarkeit des Moduls		• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule	
Zuständige Personen			
Prerequisites			
Skills to be acquired in this module			
Module contents			
Literaturempfehlungen			
Links			
Languages of instruction		German, English	
Duration (semesters)		1 Semester	
Module frequency			
Module capacity		unlimited	
Type of module		Wahlpflicht / Elective	
Module level		MM (Mastermodul / Master module)	
Examination	Prüfungszeiten		Type of examination
Final exam of module			3 Prüfungsleistungen: Klausur (2h, Gewicht: 50%), Präsentation (20min + 10min Diskussion, Gewicht: 40%) und fachpraktische Übung (Übungsaufgabe, Gewicht: 10%)
Form of instruction	Vorlesung und Übung		
SWS	4		
Frequency	SoSe und WiSe		

pre434 - Smart Grids solutions

Module label		Smart Grids solutions	
Modulkürzel		pre434	
Credit points		6.1 KP	
Workload		183 h	
Verwendbarkeit des Moduls		• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule	
Zuständige Personen			
Prerequisites			
Skills to be acquired in this module			
Module contents			
Literaturempfehlungen			
Links			
Languages of instruction		German, English	
Duration (semesters)		1 Semester	
Module frequency			
Module capacity		unlimited	
Type of module		Wahlpflicht / Elective	
Module level		MM (Mastermodul / Master module)	
Examination	Prüfungszeiten		Type of examination
Final exam of module			3 Prüfungsleistungen: Klausur (2h, Gewicht: 50%), Präsentation (20min + 10min Diskussion, Gewicht: 40%) und fachpraktische Übung (Übungsaufgabe, Gewicht: 10%)
Form of instruction	Vorlesung und Übung		
SWS	4		
Frequency	SoSe und WiSe		

pre435 - Energetic Markets

Module label		Energetic Markets	
Modulkürzel		pre435	
Credit points		4.0 KP	
Workload		120 h	
Verwendbarkeit des Moduls		• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule	
Zuständige Personen			
Prerequisites			
Skills to be acquired in this module			
Module contents			
Literaturempfehlungen			
Links			
Languages of instruction		German, English	
Duration (semesters)		1 Semester	
Module frequency			
Module capacity		unlimited	
Type of module		Wahlpflicht / Elective	
Module level		MM (Mastermodul / Master module)	
Examination	Prüfungszeiten		Type of examination
Final exam of module			2 Prüfungsleistungen: Klausur (2h, Gewicht: 50%) und Präsentation (20min + 10min Diskussion, Gewicht: 50%)
Form of instruction	Vorlesung und Seminar		
SWS	4		
Frequency	SoSe und WiSe		

phy641 - Energy Resources & Systems

Module label	Energy Resources & Systems
Modulkürzel	phy641
Credit points	6.0 KP
Workload	180 h (Attendance: 56 hrs, Self-study: 124 hrs)
Verwendbarkeit des Moduls	• Master's Programme Engineering Physics (Master) > Schwerpunkt: Renewable Energies • Master's Programme Environmental Modelling (Master) > Mastermodule • Master's Programme European Master in Renewable Energy (EUREC) (Master) > Mastermodule • Master's Programme Sustainability Economics and Management (Master) > Additional Modules • Sustainable Renewable Energy Technologies (Master) > Mastermodule
Zuständige Personen	• Agert, Carsten (module responsibility) • Knipper, Martin (module responsibility) • Knipper, Martin (Prüfungsberechtigt) • Torio, Herena (Prüfungsberechtigt) • Schmidt, Thomas (Prüfungsberechtigt)
Prerequisites	
Skills to be acquired in this module	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.
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

Literaturempfehlungen	Energy Meteorology: • IEA Word Energy Outlook (http://wordenergyoutlook.org/) • Iqbal, M. 1984: An Introduction to Solar Radiation, Academic Press, Toronto • Liou, K.-N. 2002: An Introduction to Atmospheric Radiation, Academic Press: 2nd edition, Page 2 of 39 • Peixoto, J.P. and Oort A.H. 2007: Physics of Climate Book, Surge Publishing • Rasmussen, B. 1988: Wind Energy, 2, Routledge: 1st edition • Sathyajith, M. 2006: Wind energy: fundamentals, resource analysis and economics, Springer • Stull, R.B. 1988: An Introduction to Boundary Layer Meteorology, Springer 1st edition Energy Systems: • Ramage, J.: Energy: A Guide Book (Oxford University Press, 1997) • Boyle, G. et al. (Eds.): Energy Systems and Sustainability (Oxford University Press, 2003) • Blok, K.: Introduction to Energy Analysis (Techne Press, Amsterdam, 2007) • Houghton, J.: Global Warming: The Complete Briefing, 5th Ed. (Cambridge University Press, 2015) • UNDP (Ed.): World Energy Assessment: Energy and the Challenge of Sustainability (2000/2004), http://www.undp.org/energy/weapub2000.htm • GEA: Global Energy Assessment { Toward a Sustainable Future (Cambridge University Press and International Institute for Applied System Analysis, Laxenburg, 2012), www.iiasa.ac.at/web/home/research/Flagship-Projects/Global-Energy-Assessment/Chapters_Home.en.html - Goldemberg, J. et al.: Energy for a Sustainable World (Wiley Eastern, 1988) • Nakicenovic, N., A. Grübler and A. McDonald (Eds.): Global Energy Perspectives (Cambridge University Press, Cambridge, 1998) - Khartchenko, N.V.: Advanced Energy Systems (Taylor and Francis, 1998) • IEA (International Energy Agency): World Energy Statistics and Balances 2015 - BP: Statistical Review of World Energy 2016 (http://www.bp.com/en/global/corporate/ energy-economics.html) • EIA: International Energy Outlook 2016 (www.eia.doe.gov/forecasts/ieo/) • United Nations: 2013 Energy Statistics Yearbook (2016) (unstats.un.org/unsd/energy/yearbook/)
Links	
Language of instruction	English
Duration (semesters)	1 Semester
Module frequency	Winter semester
Module capacity	unlimited
Type of module	Pflicht / Mandatory
Module level	MM (Mastermodul / Master module)
Teaching/Learning method	Lectures, Exercises

Examination	Prüfungszeiten	Type of examination
Final exam of module	At the end of the lecture period	2 Written Exams (max 90 min each)

Form of instruction	Lecture
SWS	4
Frequency	SoSe oder WiSe

Abschlussmodul

mam - Master´s Thesis Module

Module label		Master´s Thesis Module	
Modulkürzel		mam	
Credit points		30.0 KP	
Workload		900 h	
Verwendbarkeit des Moduls		• Master's Programme European Master in Renewable Energy (EUREC) (Master) > Abschlussmodul	
Zuständige Personen			
Prerequisites			
Skills to be acquired in this module			
Module contents			
Literaturempfehlungen			
Links			
Languages of instruction			
Duration (semesters)		1 Semester	
Module frequency			
Module capacity		unlimited	
Examination	Prüfungszeiten		Type of examination
Final exam of module			G
Form of instruction	Seminar		
Frequency			