Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Faculty of Life Sciences

Book of Modules

Degree Programme

Renewable Energy Systems – Environmental and Process Engineering

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Book of Modules

M.Eng. Renewable Energy Systems – Environmental and Process Engineering

Faculty of Life Sciences

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(Examination regulations for first year students from WS 2015/16)

Fakulty of Life Sciences
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Inhalt

Ziele und Kompetenzprofil des Master-Studiengangs „Renewable Energy Systems – Environmental and Process Engineering“

Ziele des Studiengangs insgesamt

Der Masterstudiengang Environmental Energy Systems ist ein konsekutiver, anwendungsorientierter Studiengang, der auf einem Bachelorstudiengang Verfahrenstechnik oder Umwelttechnik oder einem verwandten Ingenieursstudiengang aufbaut. Die Einsatzgebiete der Absolventen sind weit gefächert. Die Studierenden werden daher im Rahmen ihres Studiums in die Lage versetzt, neben der fachlichen Arbeit auch Leitungs- und Führungsfunktionen bei der Entwicklung, Planung und Realisierung sowie bei Überwachung und Betrieb von Verfahren und Anlagen oder eine Tätigkeit im Höheren Dienst wesentliche Aufgaben durchzuführen. Mit dem erfolgreichen Abschluss sollen die Absolventen/innen damit auch eine Voraussetzung für die Zulassung zum wissenschaftlichen Studium mit dem Ziel der Promotion erfüllen.

Der Studiengang bietet nach einer Regelstudienzeit von 1,5 Jahren die Qualifikation eines Master of Engineering. Das Lehrangebot im ersten Studienjahr besteht aus insgesamt 16 Modulen. Im dritten Semester liegt die Masterarbeit im Umfang von 6 Monaten. Die Studieninhalte teilen sich in Vorlesungen, Seminare, Praktika und Projektarbeit. Der Erwerb von Schlüsselqualifikationen wird einerseits in eigenen Veranstaltungen vermittelt und ist weiterhin in viele Veranstaltungen integriert. Dies wird dadurch realisiert, dass Vorträge und Präsentationen in die Veranstaltungen eingestreut sind sowie Fallstudien, Einschätzungen von Entwicklungen und Übersichtsbeiträge in Gruppen- und Einzelarbeiten durchgeführt werden. Schriftliche Arbeiten, Vorträge und Diskussionsbeiträge erfolgen vorwiegend in englischer Sprache.

Wesentliche profilbildende Ziele sind.

1. Erwerb von vertieften Kenntnissen und Kompetenzen in den Spezialgebieten der Regenerativen Energien wie z.B. Wind-, Bio- und Solarenergie und der Anbindung von Regenerativen Energien an bestehende Versorgungsnetze.
2. Befähigung zur Anwendung wissenschaftlicher Methoden in der Praxis und Forschung sowie zur Entwicklung von Lösungskonzepten für die Praxis auf der Grundlage wissenschaftlicher Erkenntnisse.
3. Erwerb von Kompetenzen zur Entwicklung anwendungsorientierter Methoden.
4. Herausbildung intellektueller und sozialer Kompetenzen durch Vermittlung von abstraktem, analytischem über den Einzelfall hinausgehendem und vernetztem Denken, Vermittlung der Fähigkeit, sich schnell methodisch und systematisch in Neues, Unbekanntes einzuarbeiten, Förderung von Selbständigkeit, Kreativität, Offenheit und Pluralität, Förderung von Kommunikationsfähigkeit und Fähigkeit zum interdisziplinären Arbeiten.

Überblick über zu erreichende Lernergebnisse und Kompetenzen

Die Studierenden erwerben vertieftes Wissen in fortgeschrittenen Grundlagen der Mathematik und Datenverarbeitung. Sie erlangen außerdem fundierte Kenntnisse in den Gebieten Windenergie, Solartechnik und Bioenergie. Darüber hinaus können wahlweise Kenntnisse in der Simulation von Windenergie- und Biogasanlagen erworben werden. Außerdem kann in weiteren optionalen Modulen Wissen zu Brennstoffzellen, Prozesswärme Nutzung, fortgeschrittener elektrischer Energietechnik, Netzanbindung sowie Regelungstechnik erworben werden.

Die Vertiefung von Schlüsselkompetenzen wird durch die Vermittlung von Kenntnissen über Projektfinanzierung, Marketing, Anlagenbaus, Projektmanagement und ökonomischer Projektbewertung gewährleistet.

Die Studierenden sind damit in der Lage, Anlagen zur Gewinnung regenerativer Energien (z.B. Biogasanlagen, große Solaranlagen, Windparks etc.) zu konzipieren und zu konstruieren, ihren Bau zu überwachen und fertige Anlagen zu betreiben. Sie können Experimente durchführen, Daten interpretieren und mit dem Computer simulieren. Sie lernen, das Wirken der Systeme auf die Umwelt unter Berücksichtigung technischer, sozialer, ökonomischer und ökologischer Gesichtspunkte zu bewerten. Dabei können sie auch nicht technische Auswirkungen der Ingenieurtätigkeit systematisch reflektieren und in ihr Handeln verantwortungsbewusst einbeziehen. Sie sind in der Lage sich zügig methodisch und systematisch in neues, unbekanntes einzuarbeiten und Verantwortung in Wissenschaft, Industrie, Ingenieurbüros und Behörden zu übernehmen.

Der Abschluss Master of Engineering führt zu einer international vergleichbaren Qualifikation.

Praxisbezug, Forschungsbezug, Interdisziplinarität

In das Curriculum sind zahlreiche Praxiseinheiten integriert (Energy Practice, Biogas Engineering Practice, Project Work). Darüber hinaus sind in vielen Veranstaltungen praktische Anteile enthalten. Z.B. werden in der Vorlesung „Data Acquisition and Processing“ Vorlesungsinhalte im Labor mit LabView trainiert und im Modul 12 und 13 werden die Inhalte von Computational Fluid Dynamics bzw. Advanced Control Systems in praktischen Übungen mithilfe von wissenschaftlicher Simulationssoftware umgesetzt.

Einen besonderen Stellenwert für den Praxisbezug hat ferner die Masterarbeit, die bevorzugt in einem Unternehmen der Branche der Erneuerbaren Energien stattfinden soll oder in einer wissenschaftlichen Forschungsgruppe an der HAW Hamburg oder an externen Instituten mit Ausrichtung auf Erneuerbare Energien. Die Studierenden vertiefen hier ihre im ersten Studienjahr erworbenen Kenntnisse in einem Umfeld mit hohem Bezug zu aktuellen praktischen und ingenieurswissenschaftlichen Aufgabenstellungen aus der Wirtschaft bzw. aus Forschung und Entwicklung. Dadurch erhalten die Studierenden einen echten Einblick in das ingenieursmäßige Berufsumfeld.

Nicht zuletzt ist ein Praxisbezug prinzipiell auch dadurch gegeben, dass jeder Lehrende mehrjährige Berufspraxis außerhalb der Hochschule vorweisen kann, so dass sichergestellt ist, dass die Lehre entsprechend den Bedürfnissen der Praxis ausgerichtet wird.

Die mit dem Masterstudium eng verzahnte praxisorientierte Forschung an der Fakultät Life Sciences findet unter anderem im Forschungsschwerpunkt (FSP) Biomassenutzung Hamburg und im Forschungs- und Transferzentrum „Application of Life Sciences“ (FTZ ALS) statt. Forschungsergebnisse fließen kontinuierlich in die Vorlesungen ein. Die Masterthesis kann auch in diesen Bereichen angefertigt werden.

Die Einbindung der Aktivitäten der Fakultät in das Competence Center für Erneuerbare Energien und Energieeffizienz (CC4E) an der HAW Hamburg ermöglicht den Studierenden ferner, Einblick in weitere interdisziplinäre Forschungsprojekt zu bekommen sowie den Studiengegenstand auch aus der Perspektive anderer Fachbereiche wie Maschinenbau, Elektrotechnik, Wirtschaft aber auch Medien und Kommunikation kennenzulernen. Eine Teilnahme der Studierenden an entsprechenden Ringvorlesungen, Tagungen und Workshops an der HAW Hamburg wird unterstützt.

Darüber hinaus besteht die Möglichkeit sich in nationalen und internationalen Kooperationsprojekten und Austauschprogrammen der Fakultät zum Thema Energie einzubringen. Hier eine Auswahl von Projekten aus der Vergangenheit bzw. von fortlaufenden Projekten:

- Summer School in deutsch-türkischer Zusammenarbeit

- Projekte JELARE und REGSA zum Thema der regenerativen Energieerzeugung im Austausch mit lateinamerikanischen Hochschulen (FTZ ALS)
- DIREKT-Projekt zum Thema klimarelevante Maßnahmen auch im Energiesektor für gefährdete Inselstaaten (FTZ ALS)
- GPEE: German Polish Energy Efficiency Project (FTZ ALS)
- Projekte im CC4E: Smart Power Hamburg, e-harbours
- ERASMUS-Austausch insbesondere folgenden Hochschulen:
    - Dalarna University in Borlänge, Schweden im dortigen Masterprogramm Solar Energy Engineering
    - Bosporus University in Istanbul, Türkei im dortigen Masterprogramm Environmental Engineering
    - Universidad de País Vasco, Bilbao, Spanien im dortigen Masterprogramm zur Netzintegration von Erneuerbaren Energien.

Aims and competence profile of the master programme
"Renewable Energy Systems – Environmental and Process Engineering"

General aims of the master programme

The master programme "Renewable Energy Systems – Environmental and Process Engineering" is a consecutive and practice-oriented programme which is based on a bachelor programme of environmental engineering or process engineering or related programs in engineering. There is a wide field of jobs for graduates. Therefore, beside of engineering skills students are enabled also to take management positions in development, planning and execution as well as in monitoring and operation of processes and systems or to start a career in the higher grade of government service. Graduates fulfil the formal and scientific requirements to start a PhD-programme.

After one and a half years of regular studies successful students are awarded by the degree of a "Master of Engineering (M.Eng.)". In the first year of study lectures, seminars, project work and laboratory work are organized in 16 modules. In the third semester the master thesis has to be elaborated within a time frame of 6 months. Key skills are trained both in specialized courses and integrated in the engineering courses. This is realized by student's presentations, case studies and discussions based on individual work or team work of students. Home work, presentations and discussion are mainly in English.

Important and characteristic aims are:

1. To gain deepened knowledge and competences in the specialized field of renewable energy systems like wind turbines, bio gas system, bio fuel production, solar energy systems and the integration of these systems into the utility grid.
2. To train the use of scientific methods in practice and research in order to develop new solutions for the industrial application based on scientific fundaments.
3. To gain competences to develop practice-oriented methods.
4. To train intellectual and social competences by impart cross-linked thinking which enables to abstract from given examples. Furthermore to train the ability to quickly acquaint oneself methodically and systematically in new subjects, to promote independence, creativity, openness and pluralism, communication skills and ability to interdisciplinary work.

Overview of learning outcomes and competences to be achieved

Students gain deeper knowledge in advanced principles of mathematics and computing. They also gain a sound knowledge in the areas of wind energy, solar energy and bio energy. In addition, they can acquire knowledge in the simulation of wind energy and biogas plants by choosing related courses. In additional moduls students can learn about fuel cells, process heat, advanced electric power engineering, electrical grid integration, and advanced control systems.

The training of key skills is provided by the imparting of knowledge on project financing, marketing, project management and project economic evaluation in specialized courses.

Students are enabled to plan and construct plants for producing renewable energy (e.g. biogas plants, large solar plants, wind farms) and to supervise their construction and operation. They can perform experiments, interpret data and simulate with the computer. They learn to evaluate the effect of the systems on the environment, taking into account technical, social, economic and environmental considerations. They can also reflect non-technical implications of engineering activities systematically and involve responsibly in their actions. They are enabled to quickly, methodically and systematically familiarize with new subjects, and to take responsibility in science, industry, consulting firms and government.

The degree "Master of Engineering" leads to an internationally comparable qualification.

Reference to practice and research, interdisciplinarity

In the curriculum, manifold practical work is integrated (Energy Practice, Biogas Engineering Practice, Project Work). In addition, in several courses practical parts are included. E.g. in the course "Data Acquisition and Processing" course content is trained in the laboratory by using LabView and in module 12 and 13 the content of Computational Fluid Dynamics or Advanced Control Systems, respectively, is integrated to practical work with scientific simulation software.

Another key to practical relevance is the master thesis which should be executed in a company of the renewable energy branch or in research groups of the university or of external scientific institutes which are focused on renewable energy. During the master thesis students deepen their knowledge which they gained in the first year of studies in an environment of high relevance to practical aspects and engineering science. By this they also got a deeper insight to the professional working environment of engineers.

Last but not least, a practical reference is in principle given by the fact that each professor or lecturer can refer to several years of work experience outside the university, so that it is ensured that the teaching is oriented towards the needs of practice.

The masters program is closely linked to the practical research at the Faculty of Life Sciences, mainly organized in the Research Group “Use of Biomass, Hamburg” (Forschungsschwerpunkt (FSP) Biomassenutzung Hamburg) and the “Research and Technology Transfer Application of Life Sciences” (FTZ ALS). Research results are continuously transferred to the lectures. Students also can do their master thesis in these groups.

The integration of the activities of the faculty in the Competence Center for Renewable Energy and Energy Efficiency (CC4E) at the HAW Hamburg allows students to study subjects from the perspective of other disciplines such as mechanical engineering, electrical engineering, economy as well as media and communication. The participation of students in the lecture series, conferences and workshops at the HAW Hamburg is supported.

In addition, students can take part in national and international cooperation projects and exchange programs of the faculty in the field of renewable energy. A selection of activities is given in the list below:

- Summer School in German-Turkish cooperation
- Projects JELARE und REGSA about renewable energy generation in cooperation with universities in Latin-American (FTZ ALS)
- DIREKT-project about climate change relevant measures including renewables in cooperation with endangered islands GPEE: German Polish Energy Efficiency Project (FTZ ALS)
- GPEE: German Polish Energy Efficiency Project (FTZ ALS)
- Projects in the CC4E: Smart Power Hamburg, e-harbours
- ERASMUS-exchange in particular with partners as follow :
  - Dalarna University in Borlänge, Sweden in their master program “Solar Energy Engineering”
  - Bosporus University in Istanbul, Turkey in their master program “Environmental Engineering”
  - Universidad de País Vasco, Bilbao, Spain in their master program about electricity grid integration of renewable energy systems.

Studienverlauf / Structure of the master program

Structure of the master program

Modules	Semester
Mathematics Data Acquisition Wind Energy Energy Practice Bioenergy - Biofuels Bioenergy - Biogas Plant Engineering and Project Management Solar Energy – PV Systems Solar Energy - Converter Energy Conversion Electrical Engineering Numerical Simulation for Renewable Energy Systems Method and Tools for advanced Control Project Business Skills	1st and 2nd semester 60 CP
Master Thesis	3rd semester 30 CP

Modulübersicht / Overwiev of modules

1	2	3	4	5	6	7	8	9	10
Nr.	**Modul**	**ECTS- Credits**	**Semester**	**Lehrveranstaltung**	**Lehrveranstaltungs-art**	**SWS**	**Prüfungsart**	**Prüfungsform**	**Gruppengröße**
1	Mathematics	5	1	Numerical Mathematics	VL	4	PL	K,M	25
2	Data Acquisition	5	1	Data Acquisition a. Processing	VL	4	PL	K,M	25
3	Wind Energy	5	2	Wind Turbines	SeU	2	PL	K,M, R, FS	25
			2	Assessment of Wind Energy Projects	S	2			25
4	Energy Practice	5	2	Energy Practice	Prak	3	SL	LA	12,5
5	Bioenergy - Biofuels	5	2	Biofuels	SeU	4	PL	K,M	17,5
6	Bioenergy - Biogas	5	1	Biogas Engineering	SeU	2	PL	K,M	17,5
			1	Biogas Engineering Practice	Prak	2	SL	LA	17,5
7	Plant Engineering and Project Management	5	1	Plant Engineering	SeU	2	PL	K,M	17,5
			1	Project Management	SeU	2			17,5
8	Solar Energy - PV Systems	5	1	PV System Engineering	SeU	4	PL	K,M	17,5
9	Solar Energy - Converter	5	1	Solar Cells	SeU	2	PL	K,M	17,5
			2	Solar Thermal Systems	SeU	2			17,5
10	Energy Conversion	5	2	Fuel Cells and Batteries	SeU	2	PL	K,M	17,5
			2	Process Heat	SeU	2			17,5
11	Electrical Engineering	5	1	Advanced Electrical Engineering	SeU	2	PL	K,M	17,5
			2	Power Electronics and Grids	SeU	2			17,5
12	Numerical Simulation for Renewable Energy Systems	5	1	Computational Simulation Techniques	SeU	2	PL	K,M,FS,KO	17,5
			1	Windturbine Design with CFD	SeU und Prak	2	SL	LA	17,5
				alternativ					17,5
			1	Computational Simulation Techniques	SeU	2	PL	K,M,FS,KO	17,5
			1	CFD Simulation for Biogas Plants	SeU und Prak	2	SL	LA	17,5
13	Methods and Tools for advanced Control	5	2	Advanced Control Systems (ACS)	SeU	2	PL	K,M,R	17,5
			2	ACS: Simulation and Optimization Tools	SeU und Prak	2	SL	LA	17,5
14	Project	5	1/2	Project Work	KGP	2	SL	Pj	17,5
15	Business Skills	5	2	Project Finance	SeU	2	SL	K,M,R,Pj	25
			2	Marketing Strategy	SeU	2			25
	Summe 1	**35**		Pflichtmodule					
	Summe 2	**25**		Wahlpflichtmodule					
16	Master Thesis	30	3	Master Thesis			PL	MT	1

Pflichtmodule
Auswahlmöglichkeit: Modul 5 oder Modul 6 (Wahl beider Module möglich)
Auswahlmöglichkeit: Modul 8 oder Modul 9 (Wahl beider Module möglich)

SeU: Seminaristischer Unterricht, Prak: Laborpraktikum, KGP: Kleingruppenprojekt, S: Seminar, VL: Vorlesung
SL: Studienleistung (unbenotet), PL: Prüfungsleistung (benotet)
K: Klausur, M: Mündliche Prüfung, R: Referat, Pj: Projekt, LA: Laborabschluss, KO: Kolloquium, FS: Fallstudie
MT: Master Thesis

Modulbeschreibungen

Number of module: 1	Module: Mathematics
Coordinator of module	**Prof. Dr. A. Rodenhausen**
Lecturer	**Prof. Dr. A. Rodenhausen, Prof. Dr. Th. Schiemann**
Term/Period of time/Frequency	1st semester / within one semester / summer and winter term
Credits	5 CP
Workload	Workload 150 h: on campus program 64 h (4SWS), self-study 86 h
Status	Obligatory module
Prerequisites	Recommended: Basic skills in mathematics and in any programming language (e.g. acquired in a bachelor study)
Language	English

Skills to be acquired / Learning objectives

Subject based and methodical skills

During the course *Numerical Mathematics* the students are able to …

- analyse practical problems and identify their crucial mathematical principles,
- understand and use a wide range of numerical methods and algorithms,
- make professionally use of the MATLAB environment to implement and solve numerical applications practically,
- judge about the quality of results.

Personal and social skills

The students are able to …

- Explain the purpose and structure of a self-written MATLAB file to colleagues or classmates,
- Modify or extend MATLAB files based on communication with others,
- Present algorithms in oral or written presentations.

Contents

Numerical Mathematics

- Introduction to MATLAB programming,
- Introduction into basic problems concerning the representation of numbers and performance of arithmetic operations on a computer (types of errors, error propagation, extinction),
- Numerical Solution of Linear Equation Systems
  - Ill-conditioned linear equation systems,
  - Overdetermined linear equation systems (pseudo-inverse matrix).
- Curve Fitting and Interpolation Methods
  - Least squares fit,
  - Linearization,
  - Cubic splines.
- Optimization
  - Nelder-Mead Simplex Algorithm,
  - Use of MATLAB functions for Optimization.
- Numerical Integration
  - Trapezoidal Rule,

- Simpson's Method,
- Error estimation,
- Use of MATLAB functions for numerical integration.

- Numerical Solution of Differential Equations
  - Methods of Euler, Heun and Runge-Kutta,
  - Error estimation,
  - Use of MATLAB ODE solvers.
- Numerical Solution of Partial Differential Equations
  - Numerical derivation,
  - Approximation of a solution on a grid (e.g., Crank-Nicolson Method)
  - Solution of selected examples of PDE (e.g., the heat equation).

Related courses (associated courses)

- Numerical Mathematics

Teaching skills	The course is split in a lecture part and a practical part. Each part takes approximately the same amount of time. Lecture part: Mainly presented in form of a seminar with student interaction to discuss and present different solutions, results programming approaches by using the software tools directly. Additional exercises are to be solved by the students to improve their comprehension. Practical part: Solution of prepared exercises during the attendance. To difficulties and misunderstood issues is responded by mentoring individually. Selected solutions were presented to the study group.
Exam	There is an exam at the end of the semester covering practical exercises on the application of methods in the computer lab as well as exercises on theoretical aspects of the discussed methods in numerical mathematics.
Literature / Teaching aids	S.C. Chapra: Numerical Methods for Engineers, McGraw-Hill, 2005. A. Gilat, V. Subramaniam: Numerical Methods – An Introduction with Applications Using MATLAB, SI Version, 2011. M. Hanke-Bourgeois: Grundlagen der Numerischen Mathematik und des wissenschaftlichen Rechnens, Teubner, 2002. J. H. Mathews, K.D. Fink: Numerical Methods using MATLAB, Prentice Hall, 2004. A. Stoyanoyevitch: Introduction to Numerical Ordinary and Partial Differential Equations Using MATLAB, Wiley, 2005. W. Y. Yang et al.: Applied Numerical Methods Using MATLAB, Wiley, 2005. W. H. Press et al.: Numerical recipes in C, Cambridge University Press, New York, 1998. I.N. Bronstein, K.A. Semendyayev et al.: Handbook of Mathematics, 4th Ed. Springer, Berlin Heidelberg, 2004.

Number of module: 2	Module: Data Acquisition
Coordinator of module	**Prof. Dr. K. Förger**
Lecturer	**Prof. Dr. K. Förger**
Term/Period of time/Frequency	1st semester / within one semester / summer and winter term
Credits	5 CP
Workload	Workload 150 CP: on campus program 64 h (4 SWS), self-study 86 h
Status	Obligatory module
Prerequisites	Recommended: Basic skills in programming and mathematics (e.g. acquired in a bachelor study)
Language	English

Skills to be acquired / Learning objectives

Subject based and methodical skills

The students are able to use the computer as universal tool to solve practical problems:

- On the one hand complex simulations can be performed LabVIEW with little effort and
- on the other hand data can be acquired and processed with a computer easily.
- Measured data and signals are simulated to make the theoretical relations understandable and better applicable.

The students are able …

- to implement and evaluate data acquisition and storage algorithms,
- to identify and determine suitable parameters for data acquisition,
- to develop adequate evaluations methods for experimental data containing random contributions,
- to document experimental results completely according to scientific standards to make them reproducible,
- to interpret the evaluation of experimental data correctly (especially the results of hypothesis tests),
- to develop adequate methods to simulate the behavior of the evaluation procedures used for real experiments,
- to apply statistical methods and
- to test the developed evaluation methods by simulation to get more reliable programs.

Especially by such an approach subtle programming errors become obvious, which otherwise could be found hardly but distort the results much. That sensitizes students especially to such errors.

Additionally the students are enabled by computer simulations to analyze measurement and processing techniques (signal sampling, averaging, statistical tests etc.) if some restrictive mathematical prerequisites (e.g. sampling theorem, normal distribution of random variables) are not exactly met in practical problems. Methods which provide reliable results in such cases are highlighted as robust procedures. The students are enabled to look for robust procedures / techniques.

In practical applications the parallel acquisition and processing of measurands and the simultaneous reaction on user input is an essential requirement, which is difficult to understand and implement in text based programming languages.

On the contrary the graphical programming environment of LabVIEW enables the students:

- to design programs with parallel execution and synchronization which are easy to implement and understand.

Personal and social skills

The students are able to …

- keep one's distance to their results and especially to their own programs,
- recognize the must of software tests by using simulations with results which are known in advance,
- to assess the extent of tests for methods and procedures more precisely.

Contents

Data Acquisition and Processing

- Introduction to LabVIEW programming,
- statistical evaluation of measured data
  - basic statistical quantities (mean, variance and standard error, median etc.)
  - hypothesis tests
  - parameter estimation
- acquisition and processing
  - Fourier Transform und series: basics, examples and discretization
  - Sampling Theorem: Aliasing, smoothing Windows etc.
  - Digital Filters: linear filters (FIR and IIR)

Related courses (associated courses)

- Data Acquisition and Processing

Teaching skills	The course is split in a lecture part and a practical part which last approximately the same amount of time. Lecture part: Mainly presented in form of a seminar with student interaction to discuss and present different solutions, results, programming approaches by using the software tools directly. Additional exercises are to be solved by the students to improve their comprehension. Practical part: Solution of prepared exercises during the attendance. To difficulties and misunderstood issues is responded by mentoring individually. Selected solutions were presented to the study group.
Exam	There is a graded exam at the end of the semester (written or oral exam)
Literature / Teaching aids	W. H. Press et al.: Numerical recipes in C, Cambridge University Press, New York, 1998. I.N. Bronstein, K.A. Semendyayev et al.: Handbook of Mathematics, 4th Ed. Springer, Berlin Heidelberg, 2004. R. Jamal, H. Pichlik: LabVIEW Applications, Prentice Hall, 1998. LabView User Manual, National Instruments, January 1998. R.W. Hamming: Digital Filters, Englewood Cliffs, New Jersey, 1983. P.Profos, T. Pfeifer: Grundlagen der Meßtechnik, Oldenburg Verlag, München, 1997.

Number of module 3:	Module: Wind Energy
Coordinator of module	**Prof. Dr. T. Kampschulte**
Lecturer	**Prof. Dr. T. Kampschulte, Dipl.-Ing. K.-P. Lehmann (Guest lecturer)**
Term/Period of time/Frequency	2nd semester / within one semester / summer term
Credits	5
Workload	Workload 150 CP: on campus program 64 h (4 SWS), self-study 86 h
Status	Obligatory module
Prerequisites	Recommended: Precognition: electrical engineering, power engineering, mechanical engineering, fundamentals of measuring methods, electronics
Language	English

Skills to be acquired / Learning objectives

Subject based and methodical skills

The students are able ...

- to combine knowledge of different subjects systematically,
- to acquaint themselves with new content in a systematic way,
- to transfer theoretical knowledge to application,
- to interconnect and operate different technical devices of renewable energy generators,
- to apply and to develop suitable methods to analyze technical and scientific tasks,
- to document measurements in technical reports,
- to develop advanced knowledge about wind energy conversion systems. Students are trained and enabled to analyze locations according to the suitability for wind generators, to decide about appropriate wind turbines and to plan a wind farm with regard to technical, economical and environmental aspects. The course prepares students to work in planning office for wind energy projects, in the field of monitoring, service and maintenance of wind turbines or within environmental authorities.
- to introduce selected European energy policy with regards renewable energy,
- to discuss energy resource issues and the impact of wind energy projects,
- to discuss global and German energy use and its effect on the environment,
- to introduce wind energy conversion technologies as alternatives to fossil-based energy conversion,
- to understand and evaluate the wind energy sector as an industrial branch.

Personal and social skills

On completion of this module, students are able …

- to work in a team and to take responsibility in teamwork,
- to cope with complex technical tasks independently,
- to apply understanding of quantitative decision making techniques,
- to critically evaluate the environmental assessment of projects,
- to understand the complex nature of project assessment and critically evaluate theories, concepts, tools and models environmental impact analyses,

- to enable participants to formulate, evaluate and select from alternative technologies and location to meet legal requirements and financial interests,
- to understand and be able to explain German energy policy,
- to describe and assess the impact of wind energy projects,
- to calculate the power output wind energy projects,
- to make a critical appraisal between the technological efficacy and commercial feasibility.

Contents

Wind turbines

- Introduction:
  - History of wind energy, current status, economical importance
- Wind energy
  - Appearance of Wind, local effects, wind shear, turbulence, time variation
  - Measurement of wind, analysis of wind data, energy estimations
- Wind energy conversion systems
  - Technical concepts of conversion systems, vertical and horizontal axis, wind rotors
- Aerodynamics of modern wind turbines
  - Airfoil, Blade shape, momentum theory, rotor design
- Mechanics
  - Energy transmission, gear box, brakes, pitch control, azimuth control, housing, tower, base plates
- Electrical power generation
  - Electrical concepts, Generators, inverters, transformer, grid connection
- Operation of wind turbines
  - Power control, monitoring, servicing and maintenance

Assessment of wind energy projects:

- Wind energy markets, policies & support schemes
- Project development process & stakeholder analysis
- Assessment of potential sites, yield prognosis & optimizing, WT selection
- Permission procedures incl. environmental impact analyses
- Wind farm economics (AEP, CAPEX, OPEC and local content)
- Wind farm realization & operation
- Outlook: Offshore wind energy, repowering and innovations

Related courses

- Wind Turbines
- Assessment of Wind Energy Projects

Teaching skills	Power point presentations, students team work, arithmetic problems and exercises
Exam	oral or written exams
Literature / Teaching aids	• Lecture notes • E. Hau: Wind Turbines, 3rd edition, Springer, Berlin, 2013. • Gasch, Twele: Wind Power Plants: Fundamentals, Design, Construction and Operation, Springer, Berlin, 2012. • S. Heier: Grid Integration of Wind Energy Conversion Systems, Wiley & Sons, Chichester, 2006. • M. Sathyajith: Wind Energy - Fundamentals, Resource Analysis and Economics, Springer, Berlin, 2006. • Manwell et al.: Wind Energy Explained, Wiley, Chichester 2008. • T. Burton: Wind Energy Handbook, Wiley & Sons, Chichester, 2002. • V. Quaschning: Understanding renewable energy systems, Earthscan, London, 2007. • l. Freris, D. Infield: Renewable Energy in Power Systems, Wiley, Chichester, 2008.

Number of module 4:	Module: Energy Practice
Coordinator of module	**Prof. Dr. T. Kampschulte**
Lecturer	**Prof. Dr. F. Dildey, Prof. Dr. T. Kampschulte; Prof. Dr. S. Siegers; Prof. Dr.-Ing. R. Stank, Prof. Dr.-Ing. T. Willner** **Academic staff: J.-C. Böhmke, D. Rokita, S. Wittkowski**
Term/Period of time/Frequency	2nd semester / within one semester / summer term
Credits	5
Workload	Workload 150 CP: on campus program 48 h (3 SWS), self-study 102 h
Status	Obligatory module
Prerequisites	Recommended: Basic knowledge of renewable energy systems related to the specific lecture
Language	English

Skills to be acquired / Learning objectives

Subject based and methodical skills

The students are able ...

- to combine knowledge of different subjects systematically,
- to acquaint themselves with new content in a systematic way,
- to transfer theoretical knowledge to application,
- to interconnect and operate different technical devices of renewable energy generators in the laboratory,
- to execute experiments in the laboratory,
- to apply and to develop suitable methods to analyse experimental results,
- to document measurements in technical reports.

Personal and social skills

On completion of this module, students are able …

- to work in a team and to take responsibility in teamwork,
- to cope with complex technical tasks independently,
- to organize experimental work,
- to discuss practical and theoretical aspects of the experiments within their peer group and with the supervisor.

Contents

Energy Practice (Lab):
Several experiments in the laboratory on renewable energy systems:

- Temperature dependency of solar cells
- Electrical characterization of photovoltaic modules and generators
- Performance of fuel cells
- Production of Biodiesel 1 and 2
- Numerical determination and analysis of wind turbines

• Simulation of PV systems • Spectral response of solar cells • Solar Thermal system	
Related courses • Energy Practice (Background of the lectures from modules: Wind Energy, Bioenergy, Plant Engineering, Solar Energy, Solar Thermal Systems, Energy Conversion, Numerical Simulation for renewable energy systems)	
Teaching skills	Lab work in small teams, technical reports, presentation of results
Exam	technical report on experiment
Literature / Teaching aids	• Lecture notes of related modules • Lab instructions (for Energy Practice) • Technical manuals (for Energy Practice) • Literature of the related lectures (for Energy Practice)

Number of module: 5	Module: Bioenergy - Biofuels
Coordinator of module	**Prof. Dr.-Ing. Th. Willner**
Lecturer	Prof. Dr.-Ing. Th. Willner
Term/Period of time/Frequency	2nd semester / within one semester /summer term only
Credits	5 CP
Workload	Workload 150 CP: on campus program 64 h (4 SWS), self-study 86 h
Status	Optional module
Prerequisites	Recommended: Basic knowledge in Thermodynamics and Chemistry
Language	German or English

Skills to be acquired / Learning objectives

Subject based and methodical skills

The students are able to ...

- identify and assess global challenges of energy supply quantitatively based on material and energy flow data;
- analyze and present concepts of alternative fuel generation based on thermodynamic, chemical, ecological, economical and scientific data;
- estimate potentials and climate relevance of biofuel scenarios;
- analyze and assess publicly discussed statements concerning problems of alternative fuel supply, climate change and food production based on own calculations;
- evaluate and discuss own concepts of biofuel production including optimization options;
- use literature sources according to scientific requirements.

Personal and social skills

The students are able to …

- reach the learning objectives by creative learning and adequate time management;
- present scientific assessment results based on literature data and own calculations;
- generate and present results from team work.

Contents

- global challenges of energy supply considering demand, potentials, climate change and CO_2 balances
- thermodynamic, chemical, ecological and economical fundamentals of conventional and alternative fuels
- Chemistry of biomass
- Chemistry and thermodynamics of biological and thermochemical conversion of biomass into liquid and gaseous fuels
- 1st, 2nd and 3rd generation biofuels considering latest research and development results including activities at the Hamburg University of Applied Sciences

Related courses • Biofuels	
Teaching skills	Seminar type lecture Team work presentations
Exam	written or oral exam
Literature / Teaching aids	Lecture training manuscript and handouts. Examples of literature related to biofuels: • Overend, Milne, Mudge Eds.: Fundamentals of Thermochemical Biomass Conversion. Elsevier, London 1985. • Soltes, Milne: Pyrolysis Oils from Biomass – Producing, Analyzing and Upgrading. ACS Symposium Series 376, Washington DC, 1988. • Bridgewater, Kuester Eds.: Research in Thermochemical Biomass Conversion. Elsevier, London, 1988. • Bridgwater, Grassi: Biomass Pyrolysis Liquids Upgrading and Utilisation. Elsevier, London, 1991. • Fachagentur Nachwachsende Rohstoffe e.V.: Biocrudeoil. Gülzower Fachgespräche Band 28, Gülzow, 2008-10-30. • Fachagentur Nachwachsende Rohstoffe e.V.: Diverse Informationsbroschüren zu allen Arten von Biokraftstoffen; www.fnr.de • Geitmann: Mit neuer Energie in die Zukunft – Erneuerbare Energien & Alternative Kraftstoffe. European Energy Consult Holding (EECH) AG, Hamburg; Hydrogeit Verlag, Kremmen, 2005. • Kaltschmitt, Hartmann: Energie aus Biomasse – Grundlagen, Techniken und Verfahren. Springer, Berlin, 2001. • Reiser: Ermittlung von motor- und verbrennungstechnischen Kenndaten an einem Dieselmotor mit Direkteinspritzung bei Betrieb mit unterschiedlich aufbereitetem Rapsöl. Dissertation, Universität Hohenheim, 1997. • Klee: Charakterisierung verschiedener Pflanzenölkraftstoffe hinsichtlich ihrer Eignung als Dieselkraftstoffsubstitute unter besonderer Berücksichtigung ihrer chemischen und physikalischen Eigenschaften. Dissertation, Universität Kaiserslautern, 1999.

Number of module: 6	Module: Bioenergy - Biogas
Coordinator of module	**Prof. Dr. P. Scherer**
Lecturer	**Prof. Dr. P. Scherer**
Term/Period of time/Frequency	1st semester / within one semester /winter term
Credits	5 CP
Workload	Workload 150 CP: on campus program 64 h (4 SWS), self-study 86 h
Status	Optional
Prerequisites	Recommended: Basic laboratory knowledge
Language	English (Explanations of the practical course preferably done by a staff in German).

Skills to be acquired / learning objectives

In the Biogas Engineering lecture, basic characteristics and specialities of biogas engineering are presented. The microbiological basics of the biogas process are also explained.

Subject based and methodical skills

By **lecture** the students will have an overview on the possibilities and the potential of biogas technology in Germany and in Europe. They will learn the specific vocabulary to discuss biogas technology with planning engineers, investors and administrative bureaus. They will reflect and compare different BGE concepts and discuss them in the group as well as learn to evaluate scientific literature about it.

By oral presentation and written **homework** the students are able to present a topic of biogas engineering and to seek and find systematically specific literature in a scientific database. That is fundamental for the students to later accomplish a scientifically orientated master thesis.

Personal and social skills

By **lecture** the students are able …

- to experience time management and the ability to cope with pressure,
- to learn to divide the working load in small, rational portions,
- to learn team work in the practical course,
- to learn to document experimental results in a comprehensible manner.

Contents of the lecture “Biogas Engineering” Overview, energetical considerations, vocabulary, internet address, books, BGE-Policy, national regulations, process biology, anaerobic food chain, dominance of H_2-CO_2 utilizing methanogens in biomass plants, stage or 2-stage biogas plants, gas yields by batch tests, causes of different methane contents, biogas-reactor technologies: “wet and dry” anaerobic digestion processes, loading rate, hydraulic retention time, diversifications and examples of operational analytics (toxicity of ammonium and H_2S). Examples of biogas full scale technologies, equipment, feeding techniques, agitators. **Content of the practical course “Biogas Engineering”** Quantitative anaerobic digestions of biomass are performed simultaneously in mini-fermenters. The mini-fermentations are recorded online and many of them are equipped with methane sensors. Six work stations with up to 96 mini-fermenters in series are ready for use by max. 12 participants. Test-cellulose serves as test substrate. Different loading rates with a different inoculum/substrate-rate are applied. By gas yields and methane analyses the degradations rates are estimated and compared with other substrates. They are the basis for planning a full scale plant. There is no restriction on a special time for students to be present for the practical course. The days to present can be Thursday or Friday, but not Wednesday (every Wednesday a parallel basic practical course on microbiology is conducted in the laboratory for Applied Microbiology). Time for about two introductions and two discussions has to be reserved The experimental equipment belongs to the research centre “Hamburg biomass utilization”.	
Related courses	• Biogas Engineering • Biogas Engineering Practice
Exam	The exam is a seminar-style power point presentation plus a written version with cited literature about a subject selected from the EMIL-platform or a personally determined one (on demand without a mark; also attainable for guest auditors) Recorded protocol of the practical course according to previously defined targets for each dual group. The protocol is personally discussed with the responsible professor. One printed version for each dual group is obligatory. Protocols of the performed experiments and fermentations, generally without a mark.
Literature / Teaching aids	No fixed text book Lecture notes are published at the E-Learning-platform Links to literature is given in the courses

Number of module: 7	Module: Plant Engineering and Project Management
Coordinator of module	**Prof. Dr. V. D. Kunz**
Lecturer	**Prof. Dr.-Ing. F. Beyer, Prof. Dr. V. D. Kunz**
Term/Period of time/Frequency	1st semester / within one semester / winter term
Credits	5 CP
Workload	Workload 150 CP: on campus program 64 h (4 SWS), self-study 86 h
Status	obligatory module
Prerequisites	None
Language	English

Skills to be acquired / Learning objectives

Subject based and methodical skills
By the end of this unit students are able to …

- structure and plan complex plant construction projects,
- specify major criteria and approaches in product and process development and optimization,
- differentiate between the different phases of a project incl. their content, main deliverables and interactions,
- differentiate between the characteristic approaches in different industries (wind, solar, (bio-chemical),
- understand the concepts of product development and product / project life cycle management,
- be aware of different project management techniques and frameworks,
- Successfully conceptualize, plan, execute and terminate projects.

Personal and social skills
On completion of this module, students are able to …

- apply the special knowledge gained in engineering and construction of plants,
- analyse and classify complex structures and to apply their knowledge to fulfill defined targets,
- work task-oriented, independently and self-critically in a project team and to accept the different roles in the team,
- apply and understand quantitative and qualitative decision making techniques,
- critically evaluate the most appropriate business models,
- understand the role, context and purpose of project management techniques and environmental settings in an organizational context and define and execute actions.

Content
Plant Engineering (Beyer)

Projects: phases, types, structures, involved parties
Product and process development and optimization
Order acquisition, quotations, contracts
Preliminary planning, feasibility study
Basic and detail engineering
FEED

Procurement Expediting and inspection Civil and construction (Pre-)Commissioning and operation **Project Management (Kunz)** Product / project life cycle Project management frameworks Leadership in PM Managing teams Project change and risk management Project management tools and documentation Related areas	
Related courses • Plant Engineering • Project Management	
Teaching skills	Power point presentations, essay writing, referencing
Exam	Written or oral exam
Literature / Teaching aids	• Lecture notes • Publications • Sattler, K., Kasper, W.: Verfahrenstechnische Anlagen – Planung, Bau und Betrieb, Band 1 und 2. WILEY-VCH Verlag, Weinheim, 2000. • Helmus, F. P.: Process Plant Design – Project Mangament from Inquiry to Acceptance. WILEY-VCH Verlag, Weinheim, 2008. • Ebert, B.: Technische Projekte – Abläufe und Vorgehensweise. WILEY- VCH Verlag, Weinheim, 2002. • Bernecker, G.: Planung und Bau verfahrenstechnischer Anlagen. Springer Verlag, Berlin, 2001. • Mosberger, E.: Chemical Plant Design and Construction, Ulmann's Encyclopedia of Industrial Chemistry. WILEY-VCH Verlag, Weinheim, 1992, 5th, p 477-558. • Peters, M. et al.: Plant Design and Economics for Chemical Engineers. McGraw-Hill Professional, 2003.

Number of module: 8	Module: Solar Energy – PV Systems
Coordinator of module	**Prof. Dr. T. Kampschulte**
Lecturer	**Prof. Dr. T. Kampschulte**
Term/Period of time/Frequency	1^{st} semester / within one semester / winter term
Credits	5
Workload	Workload 150 CP: on campus program 64 h (4 SWS), self-study 86 h
Status	optional
Prerequisites	Recommended: physics, electrical engineering
Language	English

Skills to be acquired / Learning objectives

Subject based and methodical skills

The students are able to ...

- develop advanced knowledge about photovoltaic (PV) systems,
- analyse locations according to the suitability for PV systems and to calculate the yield,
- decide about appropriate components and to plan a PV-system with regard to technical, economical and environmental aspects,
- work in planning office for PV projects, in the field of monitoring, service and maintenance of PV systems or within environmental authorities,
- discuss energy resource issues and the impact of solar energy projects,
- discuss global and German energy use and its effect on the environment,
- introduce solar energy as alternatives to fossil-based energy conversion,
- understand the industrial aspects of the photovoltaic sector.

Personal and social skills

The students are able to …

- translate energy need of consumers to requirements of an energy systems,
- elaborate a planning strategy for renewable / solar energy systems,
- discuss / defend technical concepts they elaborated,
- present results of a planning process/technical concepts,
- anticipate the practical constrains of a solar energy project,
- formulate, evaluate and select from alternative technologies and location to meet legal requirements and financial interests,
- make a critical appraisal between the technological efficacy and commercial feasibility,
- reach the learning objectives by creative learning and adequate time management,
- present scientific assessment results based on literature data and own calculations,
- generate and present results from team work.

Contents

1. Introduction
   scope of application, PV-technology, Energy scenarios, PV-market

2. Solar Radiation
   solar spectrum, air mass, direct and diffuse irradiance, irradiance on tilted surfaces

3. Photovoltaic Modules
electrical and mechanical characteristics, PV module design, technical standards for PV modules

4. Grid-connected PV systems
inverter, electrical layout, grid connection
yield calculation and optimization, performance ratio, simulation, monitoring
mounting systems, statics, building integrated PV (BIPV), tracking systems, economics

5. Stand-alone and hybrid systems
battery, charge controller, stand-alone inverter
load analysis, electrical system design, operation strategies
embedding of wind generators, diesel back up, hybrid systems
simulation of hybrid systems

Related courses
Photovoltaic (PV) – System Engineering

Teaching skills	Power point presentations, students team work, arithmetic problems and exercises
Exam	written or oral exam
Literature / Teaching aids	• lecture notes • DGS Guide for installers, architects and engineers: Planning and Installing Photovoltaic Systems, Earthscan, London, 2011. • A. Luque, S. Hedegus: Handbook of Photovoltaic Science and Engineering, Wiley, Chichester, 2011. • K. Mertens: Photovoltaics: Fundamentals, Technology and Practice, Wiley, Chichester, 2014. • V. Quaschning: Understanding renewable energy systems, Earthscan, London, 2007. • l. Freris, D. Infield: Renewable Energy in Power Systems, Wiley, Chichester, 2008. • T. Markwart (Ed.): Solar Electricity, Wiley, Chichester, 2001.

Number of module: 9	Module: Solar Energy – Converter
Coordinator of module	**Prof. Dr. F. Dildey**
Lecturer	**Prof. Dr. F. Dildey**
Term/Period of time/Frequency	1th and 2nd semester / two semester /
Credits	5
Workload	Workload 150 CP: on campus program 64 h (4 SWS), self-study 86 h
Status	optional
Prerequisites	Recommendend: physics, electrical engineering, electronic devices
Language	English

Skills to be acquired / Learning objectives

Subject based and methodical skills

Upon successful completion of the module, students are able to ...

- explain how solar energy is converted to electricity by a solar cell,
- describe structures and production processes of solar cells using different semiconductors and technologies,
- estimate consequences of changing cell structures on properties of devices,
- overview manufacturing process of photovoltaic modules,
- select measurement methods to ensure quality of materials, cells, and modules,
- explain how solar energy is converted to thermal use by a collector,
- understand the role of the selective absorber to minimize radiation losses,
- describe each further detail of a system like solar circuit, storage tank, or heating circuit,
- select and dimension a complete solar system with respect to different drivers,
- assess new developments of components and bivalent systems.

Personal and social skills

The students are able to …

- join solar cell or module manufacturing industry and research laboratories,
- contribute to develop low cost production processes,
- act as person to turn to for module producers,
- join collector fabrication industry and research laboratories,
- develop concepts for integration of solar thermal systems with other energy sources,
- advise consumers in planning a solar thermal plant,
- show the benefit of solar systems to save primary energy and hence to reduce CO_2-emission.

Contents

Solar Cells

Characteristics and Semiconductor Physics

ideal solar cell, real solar cell, parameters, characteristics, modules
charge transport and absorption in semiconductors, carrier lifetime and recombination, carrier diffusion, p-n junction
physical description of efficiency and temperature behaviour

From Quartz to Silicon-Wafers, Cells, and Modules

production of different crystalline and multi-crystalline silicon wafers, fabrication of standard cells and modules

Advanced Solar Cell Structures and Technologies

antireflection coating, texturing, passivation, local back surface field, interdigitated back contact cells, buried contacts, laser ablation, laser fired contacts, laser soldering, passivation by a-Si layer, heterojunction cells, further cell structures, porous silicon

Thin Film Solar Cells and Systems

materials, substrates, deposition techniques, large area modules, concentrator cells and their module technique

Measurement Techniques

I-V characteristics, spectral response, life time measurements, short circuit current topography (LBIC), electroluminescence image

Solar Thermal Systems

Special Aspects of Thermodynamics

thermal capacity and conductivity, thermal transfer and insulation, different heat loss coefficients

Collectors

structures and fabrication, materials, selective absorbers, flat-plate and evacuated tube collectors, heat pipes, thermal losses, efficiency, characteristics, flow rate

Solar Circuit and Storage Tanks

heat transfer fluid, pipes, valves and accessories, pumps, solar station, safety

short- and long-term storage, heat carriers, latent heat tanks, heat capacity and time constant, types of storage tanks, heat exchanger, stratification, hygiene

Systems

heat demand, solar fraction, solar collector cycle efficiency, saved primary energy, solar charging strategies, controller, hydraulic systems for potable water and room heating, auxiliary heat sources, system dimensioning

heat pump assisted systems, large scale systems

Solar Thermal Power Plants

Concentrating optics for solar radiation, types of collectors and systems, high temperature storage tanks

Related courses

- **Solar Cells (2,5 CP)**
- **Solar Thermal Systems (2,5 CP)**

Teaching skills	Transparency or power point presentations, arithmetic problems and exercises, comprehension questions, discussion of current papers and new developments
Exam	written or oral exam

Literature / Teaching aids	• lecture notes • A. Luque, S. Hegedus (Editors): Handbook of Photovoltaic Science and Engineering, John Wiley, Chinchester, 2011. • V. Quaschning: Understanding Renewable Energy Systems, Earthscan, London, 2007. • V. Quaschning: Regenerative Energiesysteme – Technologie, Berechnung, Simulation, Carl Hanser, München, 2013. • H.-G. Wagemann, H. Eschrich: Photovoltaik und Halbleitereigenschaften, Solarzellenkonzepte und Aufgaben, Teunbner, Wiesbaden, 2010. • Deutsche Gesellschaft für Sonnenenergie: Planning and Installing Solar Thermal Systems, Earth Scan, London, 2010. • Deutsche Gesellschaft für Sonnenenergie: Solarthermische Anlagen, 9. Auflage, 2012. • F. Späte, H. Ladener: Solaranlagen - Handbuch der thermischen Nutzung, Ökobuch, Staufen bei Freiburg, 2011. • Annual Reports of Research Laboratories (e.g. ISFH, ISE).

Number of module: 10	Module: Energy Conversion
Coordinator of module	**Prof. Dr. A. Gregorzewski**
Lecturer	**Prof. Dr. A. Gregorzewski, Prof. Dr. M. Siegers**
Term/Period of time/Frequency	2^{nd} semester/ whole semester /once a year
Credits	5 CP
Workload	Workload 150 CP: on campus program 64 h (4 SWS), self-study 86 h
Status	Optional
Prerequisites	Recommended: Thermodynamics and Heat Transfer, Chemistry
Language	German / English

Skills to be acquired / Learning objectives

Subject based and methodical skills

The students are able to …

- assess the manifold usage of thermal energy for the purpose of seawater desalination, refrigeration, power production etc., to understand the technical realization of these processes, to calculate the effort for transport, storage and support, to rate the value of different heat sources with respect to the second law of thermodynamics and to perform rough design calculation for different plant configurations and process combinations.
- assess the range and the possibilities of application of the different fuel cell types and batteries. The students are familiar with the technology of the fuel cells and are able to see the advantages of individual fuel cell types as well as of the critical points during the development and the implementation of various fuel cell types. The students are familiar with fundamentals of electrochemical energy storage and understand the principle of different types of batteries.

Personal and social skills

The students are able to …

- apply and combine basic knowledge from bachelor courses on more complex situations, independent andwithin a team,
- reach the learning objectives by creative learning and adequate time management,
- present scientific assessment results based on literature data and own calculations,
- generate and present results from team work.

Contents

Process Heat (Gregorzewski)

- Dimensioning of Heat Storages and Estimation of Heat Losses
- Economical Heat Transport
- Heat Recovery for Warm Water, Hot Water and Steam Production
- Power Production from Waste Heat and Renewable Heat Sources
- Combined Heat and Power Production (CHP)
- Part Load Behaviour of Thermal Engines
- Internal and External Heat Recovery, Multiple Utilisation of Heat
- Heat Recovery and Refrigeration by Thermal Vapour Compression
- Heat Recovery and Refrigeration by Mechanical Vapour Compression

Fuel Cells and Batteries (Siegers)

- Introduction
- Fundamentals of a Fuel Cell
- Thermodynamics
- Efficiency
- Voltage-Current-Characteristics
- Types of Fuel Cells
  - Classification of Fuel Cell Systems
  - Proton Exchange Membrane Fuel Cell (PEMFC)
  - Solid Oxide Fuel Cell (SOFC)
- Fundamentals of Electrochemical Energy Storage
- Different Types of Batteries

Related courses

Process Heat (2,5 CP), Fuel Cells and Batteries(2,5 CP)

Teaching skills	lectures (beamer, overhead-projector, black board) with integrated exercises and case studies
Exam	written or oral exam
Literature / Teaching aids	**Process Heat** Karl, Jürgen: Dezentrale Energiesysteme, Oldenbourg Verlag, München Wien, 2006. Verein Deutscher Ingenieur-GVC: VDI-Wärmeatlas, Springer-Verlag, 2006. work sheets, exemplary calculations and generalized examples **Fuel Cells and Batteries** Larminie, Dicks: Fuel Cell Systems Explained, Wiley, 2003. Kurzweil: Brennstoffzellentechnik, Vieweg Verlag, 2003. Kordesch, Simader: Fuel Cells and Their Applications, VCH-Verlag, 1996. Hoogers: Fuel Cell Technology Handbook, CRC Press, 2003. Kiehne: Battery Technology Handbook, CRC Press, 2003. Stolten, Scherer: Transition to Renewable Energy Systems, Wiley-VCH, 2013.

Number of module: 11	Module: Electrical Engineering
Coordinator of module	**Prof. Dr. V. D. Kunz**
Lecturer	**Prof. Dr. V. D. Kunz**
Term/Period of time/Frequency	1st and 2nd semester / two semester / once a year
Credits	5 CP
Workload	Workload 150 CP: on campus program 64 h (4 SWS), self-study 86 h
Status	Optional
Prerequisites	Recommended: Electrical Engineering (fundamentals)
Language	English

Skills to be acquired / Learning objectives

Subject based and methodical skills

The students will be able to …

- analyse and design of basic Dcsystems,
- analysis of 3 phase AC circuits and systems,
- understand active, reactive and apparent power. Power factor and power factor correction,
- understand the characteristics of electro-mechanic motors and generators and electronic power devices,
- understand the concepts of power electroonics and related areas.

Personal and social skills

The students are able to …

- apply and combine basic knowledge from bachelor courses on more complex situations, independent and within a team,
- reach the learning objectives by creative learning and adequate time management,
- plan renewable energy systems and to communicate with technical specialists in power engineering,
- dive deeper into specialist areas of power electronics and related fields.

Contents

Advanced Electrical Engineering

- DC Current Circuits
- Single Phase and Three Phase AC systems
- Reactive Power Compensation
- Transformers and equivalent circuits
- Power converters

Power Electronics and Grids

- Synchronous and induction motors and generators
- Electricity grid and distribution
- Power Electronic Switches
- Fundamental devices and circuits of power electronics

Related courses

- Advanced Electrical Engineering (2,5 CP)
- Power Electronics and Grids (2,5 CP)

Teaching skills	lectures with integrated exercises and case studies where applicable
Exam	Written or oral exam
Literature / Teaching aids	Freris, I.; Infield, D.: Renewable Energy in Power Systems, Wiley, Chichester, 2008. Grigsby, L.L.: The Electric Power Engineering Handbook (Electrical Engineering Handbook), CRC Press Inc, September 2000. Mohan, N.; Undeland, T. M; Robbins, W. P.: Power Electronics: Converter, Applications and Design. New York, Wiley, 1989. Quaschning, V.: Understanding renewable energy systems, Earthscan, London, 2007 Schlabach, J.; Rofalski, K.-H.: Power System Engineering: Planning, Design, and Operation of Power Systems and Equipment, Wiley-Vch, 2008. Stiebler, M.: Wind Energy System for Electric Power Generation. Berlin, Springer, 2008. Wildi, T.: Electrical Machines, Drives and Power Systems, Sperika Enterprises Ltd., New Jerse, Wiley, USA, 2002.

Number of module: 12	Module: Numerical Simulation
Coordinator of module	**Prof. Dr.-Ing. Rainer Stank**
Lecturer	**Prof. Dr.-Ing. Rainer Stank**
Term/Period of time/Frequency	1st semester / within one semester / winter term only
Credits	5 CP
Workload	Workload 150 h: on campus program 64 h (4SWS), self-study 146 h, with one third for the lecture, one third for the utilization of the software and one third to compile an individual report on the base on a CFD computation for renewable energy applications
Status	optional
Prerequisites	---
Language	German/Englisch

Skills to be acquired / Learning objectives

Subject based and methodical skills

- The students are able to apply numerical simulations and in particular CFD computations. The students are able to use commercial CFD packages in order to simulate the flow fields occurring in the area of renewable energies.
- The students know the five steps of a numerical simulation and they know the details, settings and functions of the Pre- Main- and Post-Processing.
- The students are capable to assess the quality of the numerical results by evaluating the mesh and the convergence behaviour.
- By their physical understanding the students are able to analyse the flow and to improve the flow path and/or the technical application.
- The students can identify the key parameter of the flow field and use them for further evaluations and analysis.
- The students are competent to isolate the important geometry features for the flow based on CAD data or blueprints and to generate appropriate computational meshes. They also generate converged and consistent numerical solutions.

Personal and social skills

- The students have the ability to reach the educational objectives sure and independently.
- The students can apply commercial numerical simulation tools for CFD.
- The students are in a position to communicate about all aspects of numerical simulations and the underlying physical principles.
- They learn creatively and in small teams and they analyse the numerical results together before including them in a report.
- The students have the ability to present work results in a scientific and convincing manner.
- The students are able to compare their numerical simulated results with experimental data and interpret the results of the numerical simulations with respect to their reliability.

Contents

Lecture: Computational Simulation Techniques

This lecture contains the numerical techniques to solve coupled partial differential equations including explicit algorithms, boundary conditions and spatial discretisation. The commercial software packages ANSYS CFX and CD-adapco starccm+ are introduced and used to simulate the flow fields for the investigated application. Numerical solution parameters are treated and the convergence behaviour is explained and studied.

The physical flow phenomena laminar and turbulent flow is explained and the way how to handle them in a numerical simulation is shown.

The different types of meshes suited for the numerical simulations are introduced and best practical guidelines are given to generate professional meshes as the basis for the numerical computations.

Lecture: CFD Simulation for Biogas Plants

The lecture "CFD Simulation for Biogas Plants“ deals with multi-components flows as they occur in bio gas plants. Mixtures consisting of gases or liquids and porous media are explained as well as drying processes.

The programming of additional variables within the commercial CFD packages to analyse the mixing properties, i.e. concentrations, and/or the heat transfer mechanisms is covered. Existing designs of Biogas Plants or the component parts of Biogas Plants are analysed to understand possible improvements.

Lecture: Wind Turbine Design with CFD

The lecture "Wind Turbine Design with CFD" includes the airfoil section theory and discusses the numerical investigation of the lift and drag curve with the help of CFD. The two dimensional results are transferred to 3D wing section theory in order to determine the local chord length distribution of the rotor.

Instationary computations are carried out to analyse the design parameter chord length, number of revolutions and nacelle design etc. and to determine the wind pressure force on the structure.

Related courses:

Computational Simulation Techniques (2,5 CP)
Wind Turbine Design with CFD (2,5 PC)
CFD Simulation for Biogas Plants (2,5 CP)

Teaching skills/Advanced Teaching and Learning	Presentations (projector/overhead projector) Teamwork in small groups Supervision of using the commercial software package ANSYS CFX or CD-adapco starccm+
Exam	Written or oral exam, colloquium, case study, and individual lab report
Literature/Teaching aids/Studying Material	• Script • Manuals and Tutorials of ANSYS and CD-adapco • Jiyuan Tu et all: Computational Fluid Dynamics: A practical approach, Butterworth-Heinemann. • Abbott, I.; von Doenhhoff, A.: Theory of Wing sections, Dover. • Ferziger, J.H.; Peric, M.: Computational Methods for Fluid Dynamics, Springer Verlag. • Versteeg, H.K.; Malalasekera, W.: An Introduction to Computational Fluid Dynamics, The Finite Volume Method, Pearson. • Munson et all: Fundamentals of Fluid Mechanics, Wiley. • Hau, E.: Wind Turbines, Springer Verlag. • Manwell et all: Wind Energy explained, Wiley.

Number of module: 13	Module: Methods and Tools for Advanced Control
Coordinator of module	**Prof. Dr. G. Lichtenberg**
Lecturers	**Prof. Dr. G. Lichtenberg, Dipl.-Ing. G. Pangalos**
Term/Period of time/Frequency	2^{nd} semester / within one semester / summer term
Credits	5
Workload	Workload 150 CP: on campus program 64 h (4 SWS), self-study 86 h
Status	optional
Prerequisites	Recommended: Linear Algebra, Differential Equations, Basic Linear Control (optional), Basic Mathematics and Programming
Language	English

Skills to be acquired / Learning objectives

Subject based and methodical skills

Upon successful completion of the module, students are able to ...

- understand model-based engineering methods
- model dynamical systems
  - structured, by first principles (white box)
  - unstructured, from measurement data (black box)
  - semi-structured, by adapting model parameters (gray box)
- apply model-based methods for automation tasks
  - State feedback
  - Predictive and Learning Control
  - Adaptive Control
  - Supervisory Control
- design appropriate controllers
  - fix the control structure
  - choose the controller structure
  - optimize controller parameters
- use block-oriented simulation tools, e.g. MATLAB / Simulink to …
  - build a model from physical differential-algebraic equations (white box)
  - identify parameters from measurement data (black box / gray box)
  - validate a model
  - design controllers with model-based tools

Personal and social skills

The students are able to …

- discuss control concepts in a team,
- decide which concepts are applicable,
- guide the implementation process,
- understand basics for later usage of engineering tools,
- contribute to model-based controller design (e.g. hardware-in-the-loop),
- act as person to turn to for simulation tools, e.g. MATLAB / Simulink.

Contents

Modelling

Linear and nonlinear systems
Continuous- and discrete-time systems
Continuous- and discrete-variable systems
Hybrid systems
State space models
Block diagrams
Parameter identification

Analysis

Stability
Controllability and observability
Performance

Design

State feedback and observers
Linear predictive control
Iterative learning control
Adaptive control
Response optimization

MATLAB: Matrix Computing and linear models

MATLAB programming, m-files
Data import and export
Transfer functions
State space models
Linear controller design

Simulink: Nonlinear models

Modeling continuous-time, discrete-time and hybrid systems
Solver settings
Model hierarchies
Modeling guidelines
Creating own block libraries
Controller design using Simulink

Related courses

- **Advanced Control Systems (2,5 CP)**
- **Simulation and Optimization Tools (2,5 CP)**

Teaching skills	Presentation, Whiteboard, Clickers Scientific paper discussions Computational examples MATLAB / Simulink problems and exercises
Exam	Written or oral exam, Presentations, lab report
Literature / Teaching aids	Goodwin, Graebe, Salgado: Control System Design**,** Prentice Hall, 2000 Maciejowski: Predictive Control with constraints, Prentice-Hall, 2001 Khalil: Nonlinear Systems, Prentice-Hall, 2001

Number of module: 14	Module: Project
Coordinator of module	**Prof. Dr. M. Geweke**
Lecturer	**All lecturers of the departments environmental and process engineering**
Term/Period of time/Frequency	1st or 2nd Semester
Credits	5
Workload	Workload 150 CP: on campus program 32 h (2 SWS), self-study 118 h
Status	optional
Prerequisites	--
Language	Deutsch / English

Skills to be acquired / Learning objectives

Subject based and methodical skills

The students are able to …

- analyze and to systemize complex scientific tasks in the field of renewable energy systems and to define relevant tasks out of complex problems,
- to define the state of the art of the specific task by using international reports and literature including databases,
- to get familiar with the experimental fundamentals, to develop a reasonable and effective experimental program, to conduct the experiments self consistent, to analyze the results accurately and systematically and to define further steps.

Personal and social skills

The students are able to …

- to perform the given task self consistent as a part of a team in a scientific manner,
- to identify and to define possible interfaces in interdisciplinary projects,
- to conclude and to present the results of the scientific work in a presentation and a report.

Contents

specific projects related to the scientific work done currently at the faculty life sciences of the Hamburg University of Applied Science in the field of renewable energy systems

Related courses

- Project work

Teaching skills	Discussion between supervising professor and student on the basis of experimental results and progress reports Possible presentation of preliminary results
Exam	Project report incl. presentation
Literature / Teaching aids	The required literature highly depends on the project

Number of module: 15	Module: Business Skills
Coordinator of module	**Prof. Dr. W. Beba**
Lecturer	**Prof. Dr. W. Beba, Prof. Dr. C. Decker**
Term/Period of time/Frequency	2nd semester / within one semester / summer term
Credits	5 CP
Workload	Workload 150 CP: on campus program 64 h (4 SWS), self-study 86 h
Status	Mandatory module
Prerequisites	None
Language	English

Skills to be acquired / Learning objectives

Subject based and methodical skills

By the end of this unit students are able to ...

- comprehend the rationale for using project financing,
- recognize the various perspectives of sponsors, lenders and other parties involved,
- apply a structured and systematic approach assessing the risks associated with project finance transactions,
- recognize the key characteristics of a robust project and identify weaknesses of a proposed structure,
- interpret the risks identified and propose (contractual) mechanism to allocate these risks,
- identify the various project funding sources available (equity/debt/mezzanine/bonds),
- comprehend essential credit issues in assessing project finance proposals,
- enable participants to recognize the role and contribution of marketing strategy,
- achieve aims and objectives through critical examination of marketing strategy in different business contexts / environments,
- formulate, evaluate and select alternative marketing strategies to meet marketing issues and problems whilst developing associated strategic decision-making skills.

Personal and social skills

On completion of this module, students are able to …

- apply and understand quantitative and qualitative decision making techniques,
- critically evaluate the most appropriate business models,
- understand the role, context and purpose of financial and strategic management techniques.

Content

Project Finance (Decker)

Fundamentals of project financing (financial rationale, parties involved, development phases)
State and trends of the project finance market
Role of sponsors, lenders and advisors
Project due diligence and risk identification
Risk management / contractual risk allocation
Funding of project finance transactions by equity, debt, mezzanine and/or project bonds

Role of commercial banks, international financial institutions and export credit agencies Arranging and structuring financing Introduction to project and financing documentation Introduction to legal aspects in project finance **Marketing Strategy (Beba)** Business trends including seasonality, cycles, and random variations Decision trees Deterministic strategy Environmental forces, structural inertia, life cycles, rational strategy The planning process, analysis, modernist and functional approaches developmental strategy Resources such as brands, capabilities interactive strategy Competitive exclusion, niche, benchmarking, positioning, differentiation unpredictable strategy	
Related courses • Project Finance (2,5 CP) • Marketing Strategy (2,5 CP)	
Teaching skills	Power point presentations, computer-based training phases, case studies
Exam	Written or oral exam, presentations, project report
Literature / Teaching aids	Lecture notes, books, publications

Number of module: 16	Module: Master - Thesis
Coordinator of module	**Prof. Dr. M. Geweke**
Lecturer	**All lecturers of the departments environmental and process engineering**
Term/Period of time/Frequency	3rd semester / within one semester / summer or winter term
Credits	30
Workload	900 h
Status	Obligatory module
Prerequisites	More than 240 CPs from previous courses
Language	Deutsch / English

Skills to be acquired / Learning objectives

Subject based and methodical skills

The students are able to ...

- analyse and to systemize complex scientific tasks in the field of renewable energy systems and to define relevant tasks out of complex problems with scientific methodical and analytical skills,
- to define the state of the art of the specific task by using international reports and literature including databases,
- to get familiar with the experimental fundamentals, to develop a reasonable and effective experimental program, to conduct the experiments self-consistent, to analyze the results accurately and systematically and to define further steps in case of experimental focused task,
- to review the state of the art in a critical manner, to compare the state of the art with the knowledge learned in the program, to correlate this knowledge with analog scientific fields and to develop scientific conclusions, guidelines and instructions in case of a theoretical focused task,
- to solve a given task problem based with efficient working skills and in an given time.

Personal and social skills

The students are able to …

- to perform the given scientific task self-consistent as a part of the team, to organize a team and to delegate subtasks if necessary in case of complex tasks,
- to guide and to coordinate a possible team, to moderate and to solve possible conflicts of the team,
- to identify and to define possible interfaces in interdisciplinary projects,
- to conclude and to present the results of the scientific work in a presentation and a report.

Contents

- specific projects related to the scientific work done currently at the faculty life sciences of the Hamburg University of Applied Science or companies working in the field of renewable energy systems

Related courses

- Master - Thesis

Teaching skills	Discussion between supervising professor and student on the basis of experimental results and progress reports Possible presentation of preliminary results
Exam	Report (Master- Thesis)
Literature / Teaching aids	The required literature depends highly on the project