HAW HAMBURG

Faculty of Life Sciences

Book of Modules

Degree Programme

Renewable Energy Systems – Environmental and Process Engineering

Master of Science

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Master of Science

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Faculty of Life Sciences
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Inhalt / Index

Ziele und Kompetenzprofil des Masterstudiengangs

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 zu übernehmen oder eine Tätigkeit im Höheren Dienst aufzunehmen. 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 Science. Das Lehrangebot im ersten Studienjahr besteht aus insgesamt 15 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 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 Kenntnisse in der Simulation von Energieanlagen erworben werden. Außerdem kann in weiteren optionalen Modulen Wissen zu Brennstoffzellen und Batteriespeichern, Smart Grids, fortgeschrittener elektrischer Energietechnik, Netzanbindung sowie Regelungstechnik erworben werden.

Die Vertiefung von Schlüsselkompetenzen wird durch die Vermittlung von Kenntnissen über Projektfinanzierung, internationale Energiepolitik, Anlagenbau, Projektmanagement und ökonomischer Projektbewertung gewährleistet.

Darüber hinaus können Studierende im Wahlbereich (Electives) zusätzliche Fächer wie Biogastechnik, Projektentwicklung für Wind- und Solarparks oder auch Fächer aus verwandten Masterstudiengängen wählen.

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, wissenschaftlich zu arbeiten und Verantwortung in Wissenschaft, Industrie, Ingenieurbüros und Behörden zu übernehmen.

Der Abschluss Master of Science führt zu einer international anerkannten Qualifikation.

Praxisbezug, Forschungsbezug, Interdisziplinarität

In das Curriculum sind zahlreiche Praxiseinheiten integriert (z.B. in Energy Practice oder Project Work). Darüber hinaus sind in vielen Veranstaltungen praktische Anteile enthalten. Z.B. werden in den Modulen „Numerical Mathematics“ und „Data Acquisition and Processing“ Vorlesungsinhalte im Labor mit MatLab bzw. LabView trainiert und im Modul 9 und 10 werden die Inhalte von Computational Simulation Technique bzw. Advanced Control Systems in praktischen Übungen mithilfe von wissenschaftlicher Simulationssoftware umgesetzt (siehe practical work/Praktikum in den Modulen 1, 2, 9 und 10).

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 (z.B. am CC4E) 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 in der Forschungsgruppe Biomassenutzung Hamburg und im Forschungs- und Transferzentrum „Nachhaltigkeit und Klimafolgenmanagement“ (FTZ NK) 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 Forschungsprojekte 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 aktueller Projekte und Kooperationen:

- Projekte im CC4E:
    - NEW 4.0 (Norddeutsche Energiewende)
    - X-Energy (Systemintegration Windenergie)

    - DSI (Demand Side Integration)
- ERASMUS-Austausch insbesondere folgenden Hochschulen:
    - Universidad Politécnica de Valencia, Spanien im dortigen Masterprogramm zu nachhaltigen Energiesystemen
    - 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.
    - Universitat Politècnica de Catalunya, Barcelona, Spanien in dortigen Masterprogrammen zu Nachhaltigkeit und Regenerativen Energien
    - sowie weitere Partner in Europa und weltweit

Aims and competence profile of the master programme

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 Science (M.Sc.)". 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 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 energy systems by choosing related courses. In additional modules students can learn about fuel cells, smart grids, 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, international energy policy, project management and project economic evaluation in specialized courses.

Furthermore, students can chose electives like biogas engineering or project development of wind and solar power plants or can take courses from related master programmes.

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, to do research and scientific investigations and to take responsibility in science, industry, consulting firms and government.

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

Reference to practice and research, interdisciplinarity

In the curriculum, manifold practical work is integrated (e.g. Energy Practice, Project Work). In addition, in several courses practical parts are included. E.g. in the modules “Numerical Mathematics” and "Data Acquisition and Processing" course content is trained in the laboratory by using MatLab or LabView and in module 9 and 10 the content of Computational Simulations Technique or Advanced Control Systems, respectively, is integrated to practical work with scientific simulation software (see: practical work in modules 1, 2, 9 and 10).

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 (e.g. the Competence Centre for Energy CC4E) 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 master’s programme is closely linked to the practical research at the Faculty of Life Sciences, mainly organized in the Research Group “Use of Biomass, Hamburg” (Forschungsgruppe Biomassenutzung Hamburg) and the “Research and Technology Transfer Sustainability and Climate Change Management” (FTZ NK). 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:

- Projects in the CC4E:
    - NEW 4.0 (Northern German „Energiewende“)
    - X-Energy (Energy System Integration of Wind Energie)
    - DSI (Demand Side Integration)
- ERASMUS-exchange in particular with partners as follow :
    - Universidad Politécnica de Valencia, Spain in their master programme on sustainable energy systems
    - 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.
    - Universitat Politècnica de Catalunya, Barcelona, Spain in their master programmes on sustainability and renewable energy
    - an further partners in Europe and around the world

Studienplan / Overview of modules

1	2	3	4	5	6	7	8	9	10
Nr.	Modul	Credit Points gemäß ECTS	Semester	Lehrveranstaltung	Lehr-veranstaltungs-art	SWS	Prüfungsart	Prüfungsform	Gruppengröße
1	Mathematics	5	1	Numerical Mathematics	SeU	2	PL	K,M,PF	25
			1	Numerical Mathematics, Practical Work	SeU	2			25
2	Data Acquisition	5	1	Data Acquisition and Processing	SeU	2	PL	K, M,PF	25
			1	Data Acquisition and Processing, Practical Work	SeU	2			25
3	Wind Energy	5	1	Wind Energy 1	SeU	2	PL	K,M,PF	25
			2	Wind Energy 2	SeU	2	PL	K,M,PF	25
4	Bioenergy - Biofuels	5	2	Biofuels	SeU	4	PL	K,M,PF	25
5	Solar Energy - PV Systems	5	1	PV System Engineering	SeU	4	PL	K,M,PF	16,7
6	Solar Energy - Converter	5	1	Solar Thermal Systems	SeU	2	PL	K,M,PF	16,7
			2	Solar Cells	SeU	2			16,7
7	Energy Conversion and Distribution	5	2	Fuel Cells and Batteries	SeU	2	PL	K,M,PF	16,7
			2	Smart Grids	SeU	2			16,7
8	Electrical Engineering	5	1	Advanced Electrical Engineering	SeU	2	PL	K,M,R,H,PF	16,7
			2	Power Electronics and Grids	SeU	2			16,7
9	Numerical Simulation for Renewable Energy Systems	5	1	Computational Simulation Techniques	SeU	2	PL	K,M,FS,KO,PF	16,7
			1	Windturbine Design with CFD - or - System Cases Studies with CFD	SeU & Prak	2	PVL	LA,K	16,7
10	Advanced Control Systems	5	2	Advanced Control Systems Methods	SeU	2	PL	K,M,Pj,FS,PF	16,7
			2	Advanced Control Systems Tools, Practical Work	SeU & Prak	2			16,7
11	Plant Engineering and Project Management	5	1	Plant Engineering	SeU	2	PL	K,M,R,H,PF	16,7
			1	Project Management	SeU	2	PL	K,M,R,H,PF	16,7
12	Electives	5	1 / 2	Elective 1	SeU	2	SL / PL	K,M,R,H,FS,Pj,PF	16,7
			1 / 2	Elective 2	SeU	2	SL / PL	K,M,R,H,FS,Pj,PF	16,7
13	Project Work	5	1 / 2	Project Work	KGP	2	SL	Pj	5
14	Energy Practice	5	2	Energy Practice Lab	Prak	3	SL	LA	12,5
15	Energy Policy and Finance	5	2	Project Finance	SeU	2	SL	K,M,R,Pj,PF	25
			2	International Energy Policy	SeU	2			25
	Summe 1	**35**		Pflichtmodule					
	Summe 2	**25**		Wahlpflichtmodule					
16	Master Thesis	30	3	Master Thesis			PL	MT	1

Pflichtmodule: 1, 2, 3, 4, 14, 15, 16

Wahlpflicht: Modul 5 oder Modul 6 oder beide Module

Auswahl: aus dem Modulen 7 - 13 bis zum Erreichen der nötigen Gesamtzahl an Credit Points

Erläuterungen:

SeU: Seminaristischer Unterricht, Prak: Laborpraktikum, KGP: Kleingruppenprojekt, S: Seminar

SL: Studienleistung (unbenotet), PL: Prüfungsleistung (benotet), PVL: Prüfungsvorleistung

K: Klausur, M: Mündliche Prüfung, R: Referat, H: Hausarbeit, Pj: Projekt, LA: Laborabschluss, KO: Kolloquium, FS: Fallstudie; PF: Portfolio-Prüfung

MT: Master Thesis

Die Gruppengröße dient der Berechnung des CW. Credit Points = Leistungspunkte (ECTS)

Prüfungsformen

Entsprechend § 14 APSO-INGI, jeweils in der geltenden Fassung, werden die Prüfungsformen für das anschließende Modulhandbuchwie folgt definiert:

1. Fallstudie (FS)

Die Fallstudie ist eine schriftliche Arbeit mit begründeter Lösung. In einer Fallstudie werden einzeln oder in Gruppen durch die Anwendung wissenschaftlicher Methoden und Erkenntnisse Praxisprobleme erfasst, analysiert und gelöst. Die Bearbeitung erfolgt veranstaltungsbegleitend. Die Bearbeitungszeit endet spätestens mit dem Ablauf der Lehrveranstaltung in dem jeweiligen Semester. Die Bearbeitungsdauer kann in den studiengangsspezifischen Prüfungs- und Studienordnungen näher geregelt werden.

2. Hausarbeit (H)

Eine Hausarbeit ist eine nicht unter Aufsicht anzufertigende schriftliche Ausarbeitung, durch die die oder der Studierende die selbstständige Bearbeitung eines gestellten Themas nachweist. Die Bearbeitungszeit einer Hausarbeit beläuft sich auf bis zu drei Monate. Handelt es sich bei der Hausarbeit um eine Prüfungsleistung, dann kann in der studiengangsspezifischen Prüfungs- und Studienordnung bestimmt werden, ob nach Abgabe der schriftlichen Ausarbeitung innerhalb einer Frist von in der Regel einem Monat ein Kolloquium zu halten ist. Die Dauer des Kolloquiums beträgt mindestens 15, höchstens 45 Minuten.

3. Klausur (K)

Eine Klausur ist eine unter Aufsicht anzufertigende schriftliche Arbeit, in der die Studierenden ohne Hilfsmittel oder unter Benutzung der zugelassenen Hilfsmittel die gestellten Aufgaben allein und selbstständig bearbeiten. Die Dauer einer Klausur beträgt mindestens 60, höchstens 240 Minuten.

4. Kolloquium (KO)

Ist bei einzelnen Prüfungsarten, der Bachelor- oder Masterarbeit ein Kolloquium vorgesehen, so handelt es sich dabei um ein Prüfungsgespräch, in dem die Studierenden in freier Rede darlegen müssen, dass sie den Prüfungsstoff beherrschen. Das Kolloquium ist ein Prüfungsgespräch von mindestens 15 und höchstens 45 Minuten Dauer, welches auch dazu dient, festzustellen, ob es sich bei der zu erbringenden Leistung um eine selbstständig erbrachte Leistung handelt. Kolloquien können als Einzelprüfung oder als Gruppenprüfung durchgeführt werden. Bei Gruppenprüfungen ist die Gruppengröße bei der Festlegung der Prüfungsdauer angemessen zu berücksichtigen.

5. Konstruktionsarbeit (KN)

Eine Konstruktionsarbeit ist eine schriftliche Arbeit, durch die anhand fachpraktischer Aufgaben die konstruktiven Fähigkeiten unter Beweis zu stellen sind. Die Bearbeitungszeit beträgt höchstens drei Monate.

6. Laborabschluss (LA)

Ein Laborabschluss ist erfolgreich erbracht, wenn die Studierenden die von der Prüferin oder dem Prüfer festgelegten experimentellen Arbeiten innerhalb des Semesters erfolgreich durchgeführt haben und ihre Kenntnisse durch versuchsbegleitende Kolloquien und/oder anhand von Protokollen und/oder durch schriftliche Aufgabenlösungen nachgewiesen haben. Die Dauer des Kolloquiums beträgt mindestens 15, höchstens 45 Minuten. Die schriftlichen Ausarbeitungen sind innerhalb einer von der Prüferin bzw. dem Prüfer festgesetzten Frist abzugeben. Diese Frist endet spätestens mit Ablauf des jeweiligen Semesters, in dem die zugeordnete Lehrveranstaltungsart durchgeführt wird.

7. Laborprüfung (LR)

Eine Laborprüfung besteht aus einem Laborabschluss und am Ende der Lehrveranstaltung aus einer abschließenden Überprüfung der Leistung. Bei dieser Überprüfung sollen die Studierenden eine experimentelle Aufgabe allein und selbständig lösen. Die Dauer der Überprüfung beträgt mindestens 60, höchstens 240 Minuten.

8. Mündliche Prüfung (M)

Eine mündliche Prüfung ist ein Prüfungsgespräch, in dem die Studierenden darlegen müssen, dass sie den Prüfungsstoff beherrschen. Sie dauert in der Regel mindestens 15 und höchstens 45 Minuten. Mündliche Prüfungen können als Einzelprüfung oder als Gruppenprüfung durchgeführt werden. Eine mündliche Prüfung ist von einer oder einem Prüfenden und Beisitzenden nach § 13 Absatz 4 abzunehmen. Die mündliche Prüfung kann anstatt von einer Prüferin oder einem Prüfer auch von mindestens zwei Prüfenden abgenommen werden (Kollegialprüfung); dabei ist die oder der Studierende in den einzelnen Prüfungsfächern verantwortlich jeweils nur von einer Prüferin oder einem Prüfer zu prüfen. Die in der mündlichen Prüfung erbrachte Leistung wird sowohl bei einer Prüfung durch mehrere Prüfer, als auch bei einer Prüfung durch eine Prüferin oder einen Prüfer und eine Beisitzerin oder einen Beisitzer nur von der oder dem Prüfenden bewertet und benotet. Die verantwortliche Prüferin oder der verantwortliche Prüfer hört die anderen Prüferinnen oder Prüfer bzw. die Beisitzerin oder Beisitzer vor der Festsetzung der Note an. Die wesentlichen Gegenstände und Ergebnisse der mündlichen Prüfung sind in einem Protokoll festzuhalten. Es wird von den Prüfenden und der oder dem Beisitzenden unterzeichnet und bleibt bei den Prüfungsakten.

9. Projekt (Pj)

Ein Projekt ist eine zu bearbeitende fachübergreifende Aufgabe aus dem jeweiligen Berufsfeld des Studiengangs. Die Ergebnisse des Projektes sind zu dokumentieren. Die Bearbeitungszeit beträgt zwischen 6 bis 26 Wochen und wird mit einem Kolloquium abgeschlossen. In der jeweiligen studiengangsspezifischen Prüfungs- und Studienordnung können zusätzliche Bedingungen zu Form, Inhalt und Ziel des Projektes und eine andere Form des Abschlusses als durch ein Kolloquium festgelegt werden.

10. Referat (R)

Ein Referat ist ein Vortrag über 15 bis 45 Minuten Dauer anhand einer selbst gefertigten schriftlichen Ausarbeitung. An das Referat schließt sich unter Führung einer Diskussionsleitung ein Gespräch an. Das Referat soll in freien Formulierungen gehalten werden. Die bei dem Vortrag vorgestellten Präsentationen bzw. Grafiken sind dem Prüfer in schriftlicher oder elektronischer Form zu übergeben. In der zusätzlichen schriftlichen Ausarbeitung, die dem Prüfer zu übergeben ist, sind die wichtigsten Ergebnisse zusammenzufassen.

11. Test (T)

Der Test ist eine schriftliche Arbeit, in dem die Studierenden nachweisen, dass sie Aufgaben zu einem klar umgrenzten Thema unter Klausurbedingungen bearbeiten können. Die Dauer eines Tests beträgt mindestens 15, höchstens 90 Minuten. In studiengangsspezifischen Prüfungs- und Studienordnungen kann bestimmt werden, dass die Einzelergebnisse der Tests mit in die Bewertung der Klausuren einbezogen werden.

12. Übungstestat (ÜT)

Ein Übungstestat ist erfolgreich abgeschlossen, wenn die Studierenden die von der Prüferin oder dem Prüfer festgelegten theoretischen Aufgaben durch schriftliche Aufgabenlösungen erfolgreich erbracht sowie ihre Kenntnisse durch Kolloquien oder Referate nachgewiesen haben. Die Dauer des Kolloquiums beträgt mindestens 15, höchstens 45 Minuten. Die schriftlichen Ausarbeitungen sind innerhalb einer von der Prüferin bzw. dem Prüfer festgesetzten Frist abzugeben. Diese Frist endet spätestens mit Ablauf des jeweiligen Semesters, in dem die zugeordnete Lehrveranstaltungsart (Übung) durchgeführt wird.

13. Portfolio-Prüfung (PP)

Eine Portfolio-Prüfung ist eine Prüfungsform, die aus maximal zehn Prüfungselementen besteht. Für die Portfolio-Prüfung sollen mindestens zwei verschiedene Prüfungsformen verwendet werden. Die möglichen verwendbaren Prüfungsformen ergeben sich aus den in § 14 Absatz 3 APSO-INGI genannten Prüfungsformen sowie semesterbegleitenden Übungsaufgaben. Die*der Lehrende legt zu Beginn der Lehrveranstaltung fest, mit welchen Prüfungselementen und mit welcher Gewichtung für die einzelnen Prüfungselemente die Portfolio-Prüfung stattfinden soll. Die einzelnen Prüfungselemente führen bei einer Prüfungsleistung entsprechend ihrer Gewichtung zu einer Gesamtnote für die jeweilige Portfolio-Prüfung. Der Gesamtumfang der Portfolio-Prüfung nach Arbeitsaufwand und Schwierigkeitsgrad darf den Umfang der Prüfungsform nicht überschreiten, wenn diese als einziges Prüfungselement gewählt werden würde.

Forms of examination

In accordance with § 14 APSO-INGI, as amended from time to time, the forms of examination for the subsequent module manual are defined as follows:

1. Case study (CS)

A case study is a piece of written work presenting a reasoned solution to a set problem. Students work either individually or in a group to establish, analyse and solve specific problems in practice by applying scientific and academic methods and findings. Case studies are set for specific classes, and must be completed in the same semester as the class and by the time the class ends. The programme-specific examination and study regulations may contain more detailed provisions on the time available for case studies.

2. Home project (HP)

A home project is a piece of written work, to be produced by the student on his or her own and outside class hours, in which the student is to prove that he or she is able to investigate and analyse a set question or subject independently. A maximum of three months is allowed for completion. If the home project constitutes an examination, the programme-specific examination and study regulations may specify whether or not a colloquium is to be held once the written project has been submitted. Colloquia should last between 15 and 45 minutes, and are generally to be held within one month of submission of the written work.

3. Written examination (WE)

A written examination is completed under supervision. Students must complete the set questions on their own, either without the use of study aids or with the use of specified study aids only. Written examinations last at least 60 and no longer than 240 minutes.

4. Colloquium (CO)

A colloquium may be required as part of certain types of examination, or in combination with the Bachelor or Master thesis. A colloquium is an oral examination in which students must prove their knowledge of the material examined, speaking and responding freely in an open discussion. A colloquium lasts at least 15 and no more than 45 minutes, and is also aimed at establishing that the written work submitted was all the student's own work. Colloquia can be organised as individual or group examinations. The size of the group for group examinations should be considered accordingly when setting the length of the examination.

5. Construction task (CT)

A construction task is a piece of written work in which the student must prove his or her design skills by solving practical tasks. A maximum of three months is allowed for completion.

6. Lab work completion (LWC)

Lab work is successfully completed when students have successfully conducted the experiments set by the examiner during the semester and have demonstrated their knowledge by taking part in corresponding colloquia and/or by submitting written records of their work and/or by completing set written tasks. Colloquia last for a minimum of 15 and a maximum of 45 minutes. The written work must be submitted by a deadline set by the examiner; the latest deadline is the end of the semester in which the class in question was taken.

7. Lab work examination (LE)

Lab work examination consists of the completion of lab work and a final examination at the end of the class. In the examination, the student is required to conduct and solve an experiment on his or her own and independently. Examinations last at least 60 and no more than 240 minutes.

8. Oral examination (OE) (or paper)

In an oral examination, a student must demonstrate in discussion with the examiner that he or she fully understands the material on which he or she is being examined. Oral examinations generally last at least 15 and no more than 45 minutes. Oral examinations may be conducted as individual or group examinations, and are to be conducted by one examiner and one assessor in accordance with Section 13 (4). An oral examination may alternatively be conducted by two or more examiners instead of one, i.e. by a panel of examiners; in such a case, the student is to be examined by one examiner only in each of the various examination subjects. Oral examinations are always assessed and graded by one examiner only, no matter whether they are conducted by several examiners or by an examiner and an assessor. The examiner responsible for grading in each case must consider the views of the other examiners/the assessor before deciding on the grade to be awarded. The main aspects covered in and results of each oral examination are to be recorded. The record is signed by the examiners and assessor and is filed with the examination documents.

9. Project (Pro)

A project is an interdisciplinary task relating to the area of industry or business for which the course is designed. The results of projects must be documented. At least 6 and no more than 26 weeks are allowed for projects. Project work is generally completed with a colloquium. The applicable programme-specific examination and study regulations may specify additional requirements in terms of the form, content and goal of the project, and may specify another form of final assessment instead of a colloquium.

10. Oral presentation (OP) or Paper (Pap)

A paper is a presentation lasting between 15 and 45 minutes on the basis of written preparation by the student. A paper is followed by a discussion led by the student or tutor. Papers should not be read out from detailed notes; students should be able to speak spontaneously. Digital or hard copies of any presentations and graphics used are to be submitted to the examiner. The detailed written paper to be submitted to the examiner should summarise the key findings and conclusions.

11. Test (T)

Tests are pieces of written work in which students demonstrate their ability to solve set tasks in a clearly defined subject area under examination conditions. Tests last at least 15 and no more than 90 minutes. The programme-specific examination and study regulations may specify that test results are to be included in the overall grade for written examinations.

12. Exercise slip (ES)

An exercise slip is awarded once a student has successfully solved the written theory tasks set by the examiner and has demonstrated his or her knowledge of the subject in a colloquium or paper. Colloquia last at least 15 and no more than 45 minutes. The written work must be submitted by a deadline set by the examiner; the latest deadline is the end of the semester in which the class type in question (exercise) was taken.

13. portfolio examination (PP)

A portfolio examination is a form of examination consisting of a maximum of ten examination elements. At least two different forms of examination shall be used for the portfolio examination. The possible forms of examination that can be used result from the forms of examination listed in § 14 paragraph 3 APSO-INGI as well as semester-long exercises. At the beginning of the course, the lecturer determines which examination elements and with which weighting for the individual examination elements the portfolio examination should take place. In the case of an examination performance, the individual examination elements result in an overall grade for the respective portfolio examination according to their weighting. The total scope of the portfolio examination in terms of workload and degree of difficulty may not exceed the scope of the examination form if this were to be selected as the only examination element.

Modulbeschreibung / Description of Modules

Module 01 – Mathematics

Renewable Energy Systems – Environmental and Process Engineering	
Mathematics	
Module number	1
Module coordinator/ person responsible	Prof. Dr. Anna Rodenhausen
Duration of the module / semester / frequency	One semester / 1st semester / once a year (winter term)
Credits (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	Contact hours: 72 h Self-study: 78 h
Type of module	Compulsory module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: Basic mathematics skills and knowledge of fundamental principles in programming as it is acquired in undergraduate studies in engineering.
Teaching language	English
Competencies gained / **Learning Outcome**	**Specialist competency (knowledge and understanding)** The students are able to… • name and explain basic principles of numerical integration and the solution of ordinary differential equations, • name and explain basic features of linear equation systems like overdetermined LESs or ill-conditioned LESs, • name and explain various approaches to curve fitting and interpolation problems, • explain the basic ideas of optimization, • outline the principal ideas for a solution of selected partial differential equations like the heat or diffusion equation, • name a variety of MATLAB functions to be used for the solution of numerical mathematics problems. **Methodological competency (use, application and generation of knowledge)** The students are able to... • select and implement an appropriate method for the numerical solution of a given ODE or an ODE system, • solve a given linear equation system, • select and implement an appropriate method for a given curve fitting or interpolation problem,

	• implement and solve a given optimization problem like estimation of parameters, • apply prepared solvers for the solution of selected partial differential equations, • apply a variety of MATLAB functions for problem solving in numerical mathematics, • debug simple MATLAB files independently, • search errors systematically and debug advanced MATLAB files in communication with others, • familiarize themselves with additional MATLAB features based on the MATLAB documentation, • analyse the quality of results and improve it, if necessary. **Social competency (communication and cooperation)** The students are able to.... • explain the purpose and the structure of a self-written MATLAB script to colleagues or classmates, • modify and extend MATLAB scripts based on communication with others. **Self-competency (scientific self-image, professionalism)** The students are able to… • develop their own point of view and present it to the group. (Example)
Content of the module	• Introduction to MATLAB and professional use of functions for numerical problem solving, • Numerical solution of ordinary differential equations and ODE systems, • Numerical Solution of Linear Equation Systems: - Ill-conditioned linear equation systems, - Overdetermined linear equation systems (pseudo-inverse matrix). • Curve fitting and interpolation methods: - Polynomial fit / least squares fit, - Linearization, - Cubic splines. • Optimization using the Nelder-Mead simplex method • Numerical solution of partial differential equations: - Numerical derivation, - Approximation of a solution on a grid (e.g. Crank-Nicolson Method), - Consideration of selected examples of PDEs.
Applicability of the module	This module delivers fundamentals for the modules 9 and 10 and when simulation software is used in other courses. Furthermore, the methods taught in this module can be applied in project work and in the master thesis, in particular when handling measurement data or when solving numerical problems.

Requirements for the award of credit points **(Study and exam requirements)**	**Regular examination type for module testing:** written examination (PL) including theoretical exercises and programming problems. The practical part is held in the computer lab. Further possible examination types: oral exam, portfolio exam. Where more than one possible examination type is used in the module, the examination type to be used is to be made known by the responsible lecturer at the start of the course.
Corresponding courses	• Numerical Mathematics (2.5 CP, 2 SHW) • Numerical Mathematics, Practical Work (2.5 CP, 2 SHW)
Learning and teaching types/ methods/ media types	• Numerical Mathematics: mainly presented in form of seminar-like teaching with student interaction and problem solving by the students. The lectures make use of a blackboard, projector and life programming with MATLAB. • Numerical Mathematics, Practical Work: beside of seminar-like teaching the students are working on materials designed for self-education in MATLAB. As well, the students solve exercises.
Literature	All references are used in the current edition. 1. Chapra, Steven, Raimond Canale: Numerical Methods for Engineers, Mc Graw Hill, 2015. 2. Gupta, Abihishek: Numerical Methods using MATLAB, Springer Verlag 2014. 3. Erwin Kreyszig: Advanced Engineering Mathematics, Wiley, 2015. 4. John H. Mathews, Kurtis D. Fink, Numerical Mathods Using MATLAB, Pearson University Press, 2014. 5. Lecture Notes and Collection of Exercises developed and provided by the lecturers.

Module 02 – Data Acquisition

Renewable Energy Systems – Environmental and Process Engineering	
Data Acquisition	
Module number	2
Module coordinator/ person responsible	Prof. Dr. Kay Förger
Duration of the module / semester / frequency	one semester / first semester / once a year
Credits (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	Contact hours: 72 h Self-study: 78 h
Type of module	Compulsory module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: Basic skills in programming and mathematics (e.g. acquired in a bachelor study)
Teaching language	English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** The students are able to use the computer as universal tool to solve practical problems: • On the one hand complex simulations can be performed by 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. • 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. **Methodological competency (use, application and generation of knowledge)** 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 evaluation 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. **Self-competency (scientific self-image, professionalism)** 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, • assess the extent of tests for methods and procedures more precisely.
Content of the module	**Contents** Data Acquisition and Processing, Lecture and Practical Work • 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) The module is split in a lecture part and a practical part (practical work). 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 (Practical Work): 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.
Applicability of the module	Data Acquisition and Processing is related to modules where measurement data are used to monitor and optimize energy systems. In particular, solar, wind, and biomass system monitoring is based on on-line data acquisition and processing. Furthermore, the methods learned in this module can be applied in the master thesis when doing laboratory experiments with electronical data acquisition.

Requirements for the award of credit points **(Study and exam requirements)**	**Regular examination type for module testing:** written exam (graded = PL) Further possible examination types: oral exam, portfolio exam Where more than one possible examination type is used in the module, the examination type to be used is to be made known by the responsible lecturer at the start of the course.
Corresponding courses	Course 1: Data Acquisition and Processing (2.5 CP, 2 SHW) Course 2: Data Acquisition and Processing, Practical Work (2.5 CP, 2 SHW)
Learning and teaching types/ methods/ media types	Course 1: seminar-like teaching Course 2: seminar-like teaching including computer work as practical work media types: presentations, lecture notes, exercises, software tools (LabView)
Literature	Each in the current edition: W. H. Press et al.: Numerical recipes in C, Cambridge University Press, New York. I.N. Bronstein, K.A. Semendyayev et al.: Handbook of Mathematics, Springer, Berlin Heidelberg. R. Jamal, H. Pichlik: LabVIEW Applications, Prentice Hall LabView User Manual, National Instruments R.W. Hamming: Digital Filters, Englewood Cliffs, New Jersey P.Profos, T. Pfeifer: Grundlagen der Meßtechnik, Oldenburg Verlag, München

Module 03 – Wind Energy

Renewable Energy Systems – Environmental and Process Engineering	
Wind Energy	
Module number	3
Module coordinator/ person responsible	Prof. Dr. Holger Schwarze
Duration of the module / semester / frequency	two semesters / first and second semester / once per year
Credits (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	Contact hours: 72 h per semester Self-study: 78 h per semester
Type of module	Compulsory module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: Precognition in physics, mathematics, mechanical engineering, electrical engineering
Teaching language	English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** Wind Energy 1: • The students gain basic knowledge of energy production with wind turbines. • They know the setup and the components of modern wind turbines and understand the principle of gaining energy by using the aerodynamic lift principle. Wind Energy 2: • The students gain knowledge in the electrical system of wind turbines • Furthermore, students gain an overview about power electronics and the requirements for grid connection. **Methodological competency (use, application and generation of knowledge)** Wind Energy 1: • The students are able to calculate the maximum power coefficient and to judge the impact of external conditions. • The students understand the BEM-method and are able to analyse the turbine's behaviour by simulation results, in order to understand the process of technical development of a wind turbine. • They are also able to apply basic economical calculation methods. Wind Energy 2:

	• The students are able to calculate stationary generator behaviour for squirrel-cage and doubly-fed induction machines as well as synchronous generators (with electrical and permanent magnet excitation). • They are able to state measures needed for grid connection of wind turbines or parks.
Content of the module	Content of Wind Energy 1: 1. Introduction, historical overview 2. Different technical concepts and components of wind turbines 3. Aerodynamics and aeroelasticity, hydrodynamics 4. Wind and modelling of wind 5. Power control and operation control 6. Structural dynamics, Campbell-diagrams 7. Multi Body Simulations 8. Rules and guidelines 9. Load calculations 10. Basic economical considerations Content of Wind Energy 2: 1. Introduction 2. History of wind power generation 3. Electrical system of wind turbines 4. Generators using the Danish principle 5. Doubly-fed induciton machines 6. Synchronoues generators 7. Power electronics 8. Grid connection
Applicability of the module	The module is related to module No. 9 where wind turbines are simulated by fluid dynamics. Furthermore, it is related to all content of electrical power generation.
Requirements for the award of credit points **(Study and exam requirements)**	Regular examination type for module testing: Wind Turbines 1: written exam (PL) Wind Turbines 2: written exam (PL) Further possible examination types: oral exam, portfolio exam Where more than one possible examination type is used in the module, the examination type to be used is to be made known by the responsible lecturer at the start of the course.
Corresponding courses	Course 1: Wind Energy 1 (2.5 CP, 2 SHW) Course 2: Wind Energy 2 (2.5 CP, 2 SHW)
Learning and teaching types/ methods/ media types	Wind Turbines 1: seminar-like teaching incl. students team work, arithmetic problems and exercises Wind Turbines 2: seminar-like teaching incl. arithmetic problems and exercises
Literature	Each in the current edition: • 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. • M. Hansen: Aerodynamics of Wind Turbines, Routledge, London, 2015

Module 04 – Bioenergy – Biofuels

Renewable Energy Systems – Environmental and Process Engineering	
Bioenergy - Biofuels	
Module number	4
Module coordination	Prof. Dr.-Ing. Thomas Willner
Duration / semester / frequency	One semester / summer semester / every other semester
Credit Points (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	Contact hours: 72 h per semester Self-study: 78 h per semester
Type of module	Compulsory module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: • Engineering and Chemical Thermodynamics (basics)
Language	• English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** Students are able to …: • create process concepts for advanced biofuels. • calculate energy efficiency of biofuel process concepts. • evaluate biofuel process concepts. • identify potential of biofuels in the context of renewable energies. • identify potential for process improvement in a given context (costs, efficiency, production increase, quality etc.). **Methodological competency (use, application and generation of knowledge)** 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. **Self-competency (scientific self-image, professionalism)**

	Students are able to …: • apply time and project management skills.
Content of module	• fundamentals of conventional and alternative fuels • biomass properties related to biofuels • engineering and chemical thermodynamics • thermodynamics applied to biofuel process concepts • 1st generation biofuels • 2nd generation biofuels • advanced 2nd generation biofuels
Applicability of module	The competencies of this lecture will help students in understanding bioenergy concepts. It can be applied in: • Plant engineering (module 11) • Project Work (module 13) • Master Thesis
Requirements for the award of credit points **(Study and exam requirements)**	Regular examination type: written exam (PL) Further possible examination types: oral exam, portfolio exam Where more than one possible examination type is used in the course, the examination type to be used is to made known by the responsible lecturer at the start of the course
Corresponding courses	Bioenergy - Biofuels
Type of course and media	Seminar-like teaching (computer with projector, blackboard, overhead and problem sheets)
Literature	Each in the current edition: Examples of literature related to bioenergy and biofuels: • Lecturer’s handout • DECHEMA position paper: Advanced alternative liquid fuels – For climate protection in global raw material change. ProcessNet, Frankfurt Juli 2017 • W. Leitner et al.: Advanced Biofuels and Beyond: Chemistry Solutions for Propulsion and Production. Angew. Chem. Int. Ed. 2017, 56, 5412-5452 • Soltes, Milne: Pyrolysis Oils from Biomass – Producing, Analyzing and Upgrading. ACS Symposium Series 376, Washington DC 1988 • Bridgwater, Grassi: Biomass Pyrolysis Liquids Upgrading and Utilisation. Elsevier Applied Sciences, New York 1991 Examples of literature related to Thermodynamics: • Ira N. Levine: Physical Chemistry. 5th Ed., McGraw-Hill, New York 2003 • Stanley I. Sandler: Chemical and Engineering Thermodynamics. 3rd Ed., John Wiley, New York 1999 • Levenspiel: Chemical Reaction Engineering

	• Michael Modell, Robert C. Reid: Thermodynamics and its Applications. 2nd Ed., Prentice-Hall, London 1983 • Daniel R. Stull, Edgar F. Westrum, Jr. & Gerard C. Sinke: The Thermodynamics of Organic Compounds. John Wiley, New York 1969

Module 05 – Solar Energy – PV Systems

Renewable Energy Systems – Environmental and Process Engineering	
Solar Energy – PV Systems	
Module number	5
Module coordinator/ person responsible	Prof. Dr. Timon Kampschulte
Duration of the module / semester / frequency	one semester / 1st semester / once a year
Credits (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	Contact hours: 72 h Self-study: 78 h
Type of module	Compulsory elective module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: physics, electrical engineering
Teaching language	English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** The students are able to.... • develop advanced knowledge about photovoltaic (PV) system concepts, • explain the technical features of components of PV systems, • set up the electrical layout of PV systems, • understand mechanical requirements regarding wind load, snow load, selection of materials for mounting systems, • identify relevant technical standards for PV components and systems • understand the industrial and economical aspects of the photovoltaic sector. **Methodological competency (use, application and generation of knowledge)** The students are able to.... • 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, • introduce solar energy as alternatives to fossil-based energy conversion, • translate energy need of consumers to requirements of an energy systems, • elaborate a planning strategy for renewable / solar energy systems. **Social competency (communication and cooperation)** The students are able to.... • discuss / defend technical concepts they have elaborated, • elaborate and present results from team work. **Self-competency (scientific self-image, professionalism)** The students are able to… • 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.
Content of the module	1. Introduction scope of application, overview PV-technology, energy scenarios 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 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 6. PV market and economics of PV systems PV market situation, historical review, outlook on future scenarios, learning rate, levelized cost of energy (LCOE), comparison of LCOE for different technologies

Applicability of the module	This module refers to: • module 6 (solar energy – converter) • module 14 (energy practice) • module 15 (energy policy and finance) • master thesis in the field of solar energy
Requirements for the award of credit points **(Study and exam requirements)**	Regular examination type for module testing: written exam (PL) Further possible examination types: oral exam, portfolio exam Where more than one possible examination type is used in the module, the examination type to be used is to be made known by the responsible lecturer at the start of the course.
Corresponding courses	Photovoltaic (PV) System Engineering
Learning and teaching types/ methods/ media types	seminar-like teaching Power point presentations, students team work, arithmetic problems and exercises, introduction to simulation software
Literature	Each in the current edition: • Mertens: Photovoltaics - Fundamentals, Technology and Practice, Wiley, Chichester 2018 • DGS: Planning and Installing Photovoltaic Systems, 3rd edition, Earthscan, London 2011 • Luque and Hegedus: Handbook of photovoltaic science and engineering, Wiley, Chichester 2011 • Quaschning: Understanding renewable energy systems, Earthscan, 2nd edition London 2016 • Häberlin: Photovoltaics, VDE-Verlag 2012 (English edition) • Scientific magazines and papers (by internet access through our library) • lecture notes and device data sheets

Module 06 – Solar Energy – Converter

Renewable Energy Systems – Environmental and Process Engineering	
Solar Energy - Converter	
Module number	6
Module coordinator/ person responsible	Prof. Dr. Timon Kampschulte
Duration of the module / semester / frequency	two semester / first and second semester/ one cycle per year
Credits (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	Contact hours: 72 h Self-study: 78 h
Type of module	Compulsory Elective Module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: physics, electrical engineering, electronic devices
Teaching language	English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** Upon successful completion of the module, students are able to ... • explain how solar energy is converted to thermal use by different types of collectors • understand the role of the selective absorber to minimize radiation losses • describe each further detail of a system like solar circuit, storage tank, ice tank, or heating circuit • complete a plant by a heat pump • elucidate the different ways to concentrate solar radiation enabling generation of electricity and continuous operation • 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 • overview manufacturing process of photovoltaic modules • estimate consequences of changing cell structures on properties of devices **Methodological competency (use, application and generation of knowledge)** The students are able to.... • select and dimension a solar thermal system

	• provide a complete coverage of heat demand by heat pump assisted or bivalent systems • separate the different ways to produce electricity by a solar thermal system • select measurement methods to ensure quality of materials, cells, and modules • define and carry out experiments to evaluate new technologies or cells structures • interpret measurements of I-V characteristics as well as EQE spectra and relate the results to the cell design **Social competency (communication and cooperation)** The students are able to.... • 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 • 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 • show the benefit of solar systems to save primary energy and hence to reduce CO_2-emission
Content of the module	**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, hybrid and PVT collectors 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, fresh water station, 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: electrical driven, adsorption and absorption types, suitable collectors, ice tanks, system behavior Solar Thermal Power Plants Concentrating optics for solar radiation, types of collectors and systems, high temperature storage tanks, sun stoves **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 behavior 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 like PERL and PERC, porous silicon, TOPCon and POLO contacts Thin Film and Concentrator Solar Cells materials, substrates, deposition techniques, large area modules, concentrator cells: technologies and characterization Measurement Techniques I-V characteristics, spectral response, life time measurements, short circuit current topography (LBIC), electroluminescence image

Applicability of the module	The content of this module gives profound background to students who also study module 5 (Solar Energy – PV systems) and to experiments executed in module 14 (Energy Practice). Furthermore, as the solar industry is a growing business, the content of this module can be applied in the master thesis in the solar industry and later on in a job position.
Requirements for the award of credit points **(Study and exam requirements)**	**Regular examination type for module testing:** written exam (graded = PL) Further possible examination types: oral exam, portfolio exam Where more than one possible examination type is used in the module, the examination type to be used is to be made known by the responsible lecturer at the start of the course.
Corresponding courses	Course 1: Solar Thermal Systems (2.5 CP, 2 SHW) Course 2: Solar Cells (2.5 CP, 2 SHW)
Learning and teaching types/ methods/ media types	seminar-like teaching Overhead transparency or power point presentations, arithmetic problems and exercises, comprehension questions, discussion of current papers and new developments
Literature	Each in the current edition: • Lecture Notes (Solar Thermal Systems) • Deutsche Gesellschaft für Sonnenenergie: Planning and Installing Solar Thermal Systems, Earth Scan, London • Deutsche Gesellschaft für Sonnenenergie: Solarthermische Anlagen • F. Späte, H. Ladener: Solaranlagen - Handbuch der thermischen Nutzung, Ökobuch, Staufen bei Freiburg • R. Stieglitz, V. Heinzel: Thermische Solarenegie – Grundlagen, Technologie, Anwendungen, Springer Verlag Berlin • Annual Reports of Research Laboratories (e.g. ISFH, ISE) • Lecture Notes (Solar Cells) • A. Luque, S. Hegedus (Editors): Handbook of Photovoltaic Science and Engineering, John Wiley& Sons, Chichester, UK • K. Mertens: Photovoltaics, John Wiley & Sons, Chichester,UK • V. Quaschning: Understanding Renewable Energy Systems, Earthscan, London • V. Quaschning: Regenerative Energiesysteme – Technologie, Berechnung, Simulation, Carl Hanser, München • A.J. Nozik et al. (editors): Advanced Concepts in Photovoltaics, Royal Society of Chemistry, Cambridge • Annual Reports of Research Laboratories (e.g. ISFH, ISE)

Module 07 – Energy Conversion and Distribution

Renewable Energy Systems – Environmental and Process Engineering	
Energy Conversion and Distribution	
Module number	7
Module coordinator/ person responsible	Prof. Dr. Marion Siegers
Duration of the module / semester / frequency	One semester / 2nd semester / every academic year
Credits (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	Contact hours: 72 h Self-study: 78 h
Type of module	Elective module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: Basic knowledge of chemistry, electrical engineering and renewable energies
Teaching language	English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** The students are able to.... • name basic concepts of fuel cells and batteries. • name and describe objectives of smart grids • distinguish between smart grids, smart markets and smart home concepts **Methodological competency (use, application and generation of knowledge)** The students are able to select an adequate type of fuel cell or battery according to a given setting • by consideration of the properties of the device as well as its advantages and disadvantages in relation to the technical environment. The students are able to describe functions and IT architecture of different smart grid projects • by using appropriate tools like the smart grid architecture model. **Social competency (communication and cooperation)** The students are able to.... • work autonomously on a task within a team and present it in the group. **Self-competency (scientific self-image, professionalism)**

	The students are able to… • develop their own point of view and present it to the group. • specify their own strong points and weak points in relation to their studies. • balance their strong points and weak points in relation to their studies.
Content of the module	**Content of course 1: Fuel Cells and Batteries** • Fundamentals of Energy Converters • Thermodynamics (excerpts) in context of Fuel Cells and Batteries • Efficiencies and Voltage-Current-Characteristics • Battery Types • Types of Fuel Cells **Content of course 2: Smart Grids** • Fundamentals of power grid architecture • Smart Grid Use Cases (frequency control, voltage control, black start capability, prevention/relief of grid congestion,) • Demand Side Integration • IT Infrastructure of Smart Grids • Smart Grid Architecture Model (SGAM)
Applicability of the module	The module finds application in context with energy storage, respectively energy conversion of wind energy (module 3: Wind Energy) or solar energy (module 5: Solar Energy – PV Systems). Also experiments in module 14 are related.
Requirements for the award of credit points (Study and exam requirements)	Regular examination type for module testing: written exam (graded = PL) Further possible examination types: oral exam, portfolio exam Where more than one possible examination type is used in the module, the examination type to be used is to be made known by the responsible lecturer at the start of the course.
Corresponding courses	Course 1: Fuel Cells and Batteries (2.5 CP, 2 SHW) Course 2: Smart Grids (2.5 CP, 2 SHW)
Learning and teaching types/ methods/ media types	seminar-like teaching, e-learning, self-studies, group work PPT-presentations, lecture notes, exercises
Literature	**Each in the current edition:** **Literature for course 1: Fuel Cells and Batteries** Larminie, Dicks: Fuel Cell Systems Explained, Wiley Kordesch, Simader: Fuel Cells and Their Applications, VCH-Verlag Hoogers: Fuel Cell Technology Handbook, CRC Press Kiehne: Battery Technology Handbook, CRC Press Stolten, Scherer: Transition to Renewable Energy Systems, Wiley-VCH

	Literature for course 2: Smart Grids Buchholz, Styczynczynski: Smart Grids – Fundamentals and Technologies in Electricity Networks, Springer Ancilloti et al.: The role of communication systems in smart grids: Architectures, technical solutions and research challenges, Computer Communications Vol. 36., Elsevier Borlase: Smart Grids: Infrastructure, Technology, and Solutions, CRC Press Uslar et. al.: Standardization in Smart grids, Springer Budka et al.: Communication Networks for Smart Grids, Springer Gottschalk, Uslar, Delfs: The Use Case and Smart Grid Architecture Model Approach

Module 08 – Electrical Engineering

Renewable Energy Systems – Environmental and Process Engineering	
Electrical Engineering	
Module number	8
Module coordinator/ person responsible	Prof. Dr. V.D. Kunz
Duration of the module / semester / frequency	two / 1st and 2nd semester / once a year
Credits (CP) / semester hours per week (SHW)	5 CP/ 4 SHW
Workload	Contact hours: 72 h Self-study: 78 h
Type of module	Elective module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: Electrical Engineering Basics / insight in basic DC and AC circuits
Teaching language	English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** **Advanced Electrical Engineering** The students are able to • analyse and design single and three phase AC systems, • understand and calculate active, reactive and apparent power, power factor and apply reactive power compensation schemes, • analyse and design basic DC-DC converters, • analyse single phase transformers including losses, • understand the characteristics of electric motors and generators **Methodological competency (use, application and generation of knowledge)** The students are able to • independently analyse and design single and three phase AC systems found in numerous renewable energy conversion systems **Power Electronics and Grids** The students are able to • analyse and understand power electronic systems • simulate power electronic components (e.g. IGBTs) and circuits with SPICE (Simulation Program with Integrated Circuit Emphasis), e.g. containing transformers, generators, motors or island grids

	• understand power electronic concepts incl. PWM, half and H bridge, inverter topologies **Social competency (communication and cooperation)** The students are able to • work autonomously on a task and present their work to the group • prepare group work and teach fellow students in hands-on sessions **Self-competency (scientific self-image, professionalism)** The students are able to • develop and present a novel topic to the group • teach and conduct the group new topics • demonstrate their problem solving skills • explain complex relationships by breaking them up in smaller chunks
Content of the module	**Advanced Electrical Engineering** • AC circuits • single phase and three phase AC systems • AC Power and compensation • DC-DC converter • transformers and equivalent circuits • synchronous and induction motor and generator **Power Electronics and Grids** • Introduction to SPICE • Theory and simulations of selected power electronic topics, e.g. fundamental power electronic devices and power electronic circuits, generators and grids
Applicability of the module	**This module can be closely linked to the following modules** • Wind Energy • Solar Energy – PV Systems • Solar Energy – Solar Cells • Energy Conversion and Distribution • Energy Practice
Requirements for the award of credit points **(Study and exam requirements)**	Regular examination type for module testing: written exam (graded = PL) Further possible examination types: oral exam, oral presentation, home paper, portfolio exam Where more than one possible examination type is used in the module, the examination type to be used is to be made known by the responsible lecturer at the start of the course.
Corresponding courses	Course 1: Advanced Electrical Engineering (2.5 CP, 2 SHW) Course 2: Power Electronics and Grids (2.5 CP, 2 SHW)
Learning and teaching types/ methods/ media types	Advanced Electrical Engineering: seminar-like teaching supported by examples and group work when applicable Power Electronics and Grids Seminar-like teaching including presentations and hands-on simulations

Literature	Each in the current edition: 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.

Module 09 – Numerical Simulation for Renewable Energy Systems

Renewable Energy Systems – Environmental and Process Engineering	
Numerical Simulation for Renewable Energy Systems	
Module number	9
Module coordinator/ person responsible	Prof. Dr.-Ing. Rainer Stank
Duration of the module / semester / frequency	one semester / 1st semester / every academic year -- winter term only
Credits (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	Contact hours: 72 h Self-study: 78 h
Type of module	Elective Module
Module prerequisites **Requirements for participation / previous knowledge**	--
Teaching language	English
Competencies gained / Learning Outcome *(if this form is used, please delete the next line)*	**Specialist competency (knowledge and understanding)** The students are able to.... • name basic concepts of the derivation and derive the governing equations for numerical simulations. • identify the key parameter of the flow field and use them for further evaluations and analysis. • isolate the important geometry features for the flow based on CAD data or blueprints and to generate appropriate computational meshes. • to apply and use numerical simulations and in particular CFD computations • use commercial CFD packages in order to simulate the flow fields occurring in the area of renewable energies. • compare their numerical simulated results with experimental data and interpret the results of the numerical simulations with respect to their reliability. **Methodological competency (use, application and generation of knowledge)** The students are able to.... • apply commercial numerical simulation tools for CFD. • apply the five steps of a numerical simulation and they know the details, settings and functions of the Pre- Main- and Post-Processing. • generate converged and consistent numerical solutions. • to assess the quality of the numerical results by evaluating the mesh and the convergence behaviour.

	• analyse the flow and to improve the flow path and/or the technical application. **Social competency (communication and cooperation)** The students are able to.... • communicate about all aspects of numerical simulations and the underlying physical principles. • learn creatively and in small teams and they analyse the numerical results together before including them in a report. • present work results in a scientific and convincing manner. • work autonomously on a task within a team and present it in the group. **Self-competency (scientific self-image, professionalism)** The students are able to… • develop their own point of view and present it to the group. • to reach the educational objectives sure and independently.
Content of the module	**Lecture: Computational Simulation Techniques** This lecture contains the physics and the derivation of the partial differential govering equations (RANS) and the numerical techniques to solve coupled partial differential equations including explicit algorithms, boundary conditions and spatial discretisation. The physical flow phenomena laminar and turbulent flow are explained and the way how to handle turbulent flow 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. Numerical solution parameters are treated, and the convergence behaviour is explained and studied. **Lab 2a: 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 and therefore the design of the 3D rotor blades of modern wind turbines. The design parameter chord length, twist, angle of attack and construction angle are used for the design. For the designed wind turbine the physical load and the performance is calculated. The commercial software package ANSYS CFX is introduced and used to simulate the flow fields for the investigated application of wind turbines. The workflow of CFD projects is introduced and general and problem taylored post processing is carried out for the investigated application. **or alternatively** **Lab 2b: System Case Studies with CFD**

	The lecture "System Case Studies with CFD“ deals with all sorts of flow in or around renewable Energy components, like Bio Gas Plants, Solar Panels or liquid Energy Storage Tanks or liquid Heating Systems. The commercial software packages ANSYS CFX and/or Siemens STAR-CCM+ are introduced and used to simulate the flow fields for the investigated application. The workflow of CFD projects is introduced and general and problem taylored post processing is carried out for the investigated application.
Applicability of the module	This module is connected with the modules 1 (“Mathematics”) and 3 (“Wind Energy”). In this module the knowledge gained in module 3 is profunded and applied to practical examples. Based on the mathematical theories and the fundamentals of Wind Energy the desgin process of Wind Turbines is explained and carried out. This module is also connected to one experimatal setup of the “Energy Practice Laboratory” module 14, where the economic aspect of the revenue of an operational Wind Turbine is treated.
Requirements for the award of credit points **(Study and exam requirements)**	Regular examination type for module testing: Course 1 (CST): Written exam (PL) Further possible examination types: oral exam, case study, colloquium, portfolio exam Course 2a (CWi) / 2b (CCS): Lab work completion (PVL) Further possible examination types: written exam Where more than one possible examination type is used in the module, the examination type to be used is to be made known by the responsible lecturer at the start of the course.
Corresponding courses	Course 1: Computational Simulation Techniques (CST): 2.5 CP, 2 SHW Course 2a: Wind Turbine Design with CFD (CWi): 2.5 CP, 2 SHW or alternatively Course 2b: System Cases Studies with CFD (CCS): 2.5 CP, 2 SHW
Learning and teaching types/ methods/ media types	Teaching and learning types, course 1: seminar-like teaching and self-study Teaching and learning types, course 2a: seminar-like teaching and lab work incl. projects, teamwork in small groups and self-study. Supervision of the usage of the commercial software package ANSYS CFX Teaching and learning types, course 2b: seminar-like teaching and lab work incl. project, teamwork in small groups and self-study. Supervision of the usage of the commercial software package ANSYS CFX and/or Siemens STAR-CCM+

Literature	Each in the current edition: • John D. Anderson: Computational Fluid Dynamics: The Basics with Applications, McGraw-Hill, 1995 • Jiyuan Tu et all: Computational Fluid Dynamics: A practical approach, Butterworth-Heinemann, 3rd Edition, 2018. • Versteeg, H.K.; Malalasekera, W.: An Introduction to Computational Fluid Dynamics, The Finite Volume Method, Pearson, 2nd edition, 2007. • Ferziger, J.H.; Peric, M.: Computational Methods for Fluid Dynamics, Springer Verlag, 4th Edition, 2019. • Munson et all: Fundamentals of Fluid Mechanics, Wiley, 7th Edition, 2012. • Hau, E.: Wind Turbines: Fundamentals, Technologies, Application, Economics, Springer,2nd Edition, 2010. • Abbott, I.; von Doenhhoff, A.: Theory of Wing sections, Dover, 1960. • Manuals and Tutorials of ANSYS CFX and Siemens STAR-CCM+

Module 10 – Advanced Control Systems

Renewable Energy Systems – Environmental and Process Engineering	
Advanced Control Systems	
Module number	10
Module coordinator	Prof. Dr. Gerwald Lichtenberg
Duration / semester / frequency	one semester / 2nd semester / once a year
Credits (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	Contact hours: 72 h Self-study: 78 h
Type of module	Elective Module
Module prerequisites	Recommended: linear algebra, calculus, basic informatics systems theory, control basics
Teaching language	English
Learning Outcome (KOM)	The students ... • design advanced controllers • using appropriate numerical tools • by methods based on state space models • which they identify from data or first principles • to improve the closed loop performance or robustness • of complex systems like renewable energy systems.
Applicability of the module	The module is equivalent to Module Advanced Control Systems within the MSc Biomedical Engineering programme.
Requirements for the award of credit points	Regular examination type for module testing: portfolio examination (PL) Further possible examination types: written exam, oral exam, project, case study Where more than one possible examination type is used in the module, the examination type to be used is to be made known by the responsible lecturer at the start of the course.
Corresponding courses	Course 1: Advanced Control Systems Methods (2.5 CP, 2 SHW) Course 2: Advanced Control Systems Tools, Practical Work (2.5 CP, 2 SHW)
Learning and teaching types/ methods/ media types	Course 1: seminar-like teaching incl. exercises, autonomous studies Course 2: seminar-like teaching and computer labs incl. project teamwork, autonomous studies
Literature	Each in the current edition: • Lecture notes

	• Current research papers • Skogestad & Postlethwaite: Multivariable feedback control, Wiley. • Khalil: Nonlinear Systems, Prentice-Hall. • Ljung: System Identification, Prentice-Hall. • Maciejowski, Predictive Control with constraints, Prentice-Hall.

Module 11 – Plant Engineering and Project Management

Renewable Energy Systems – Environmental and Process Engineering	
Plant Engineering and Project Management	
Module number	11
Module coordinator/ person responsible	Prof. Dr.-Ing. Falk Beyer
Duration of the module / semester / frequency	One semester / winter semester / every other semester
Credits (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	In-class lecture: 72 h Self-study: 78 h
Type of module	Elective module
Module prerequisites **Requirements for participation / previous knowledge**	None
Teaching language	English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** Students are able to: • differentiate between the various phases of a process plant asset life cycle • understand and define the requirements of the different phases of a process plant life cycle • define the interfaces between the different phases of a process plant life cycle. • differentiate between the various phases of a project incl. their content, main deliverables and interactions • understand different project management techniques and frameworks • successfully conceptualize, plan, execute and terminate projects. **Methodological competency (use, application and generation of knowledge)** Students are able to • structure and plan process plant engineering and construction projects • execute projects along the asset life cycle • learn to incorporate state of the art literature & publication **Social competency (communication and cooperation)**

	Students are able to …: • work task-oriented, independently and self-critically in a project team and accept different roles in the team • discuss and elaborate solutions in interdisciplinary teams. • present their own point of view / critical judgement • draft and give presentations • write papers. **Self-competency (scientific self-image, professionalism)** Students are able to …: • justify their own professional actions with theoretical and methodological knowledge and reflect on alternative designs.
Content of the module	Course 1: Plant Engineering • Projects: phases, execution structures, involved parties • Technology development • Preliminary planning, feasibility study • Basic and detail engineering, FEED • Procurement, expediting and inspection • Civil and construction • Commissioning and operation • Maintenance/inspection Course 2: Project Management • Technology Management • Product / project life cycle • Project management frameworks • Leadership in PM • Managing teams • Project change and risk management • Project management tools and documentation • Special methods like lean management, agile project management
Applicability of the module	The module can be applied in e.g.: • Project Work • Master Thesis
Requirements for the award of credit points **(Study and exam requirements)**	Regular examination type for Plant Engineering: oral presentation (PL) Further possible examination types: written exam, home project, portfolio examination or oral examination. Regular examination type in Project Management: oral presentation (PL) Further possible examination types: written exam, home project, portfolio examination or oral examination. Where more than one possible examination type is used in the course, the examination type to be used is to made known by the responsible lecturer at the start of the course.

Corresponding courses	Course 1: Plant Engineering (2.5 CP, 2 SHW) Course 2: Project Management (2.5 CP, 2 SHW)
Learning and teaching types/ methods/ media types	Seminar-like teaching (computer with projector, blackboard, overhead and problem sheets)
Literature	Each in the current edition: Plant Engineering: • Helmus, F. P.: Process Plant Design – Project Management from Inquiry to Acceptance. WILEY-VCH Verlag, Weinheim, 2008. • Moran, Sean: An applied guide to process and plant design. Butterworth-Heinemann, Oxford 2015 • 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. • Sattler, K., Kasper, W.: Verfahrenstechnische Anlagen – Planung, Bau und Betrieb, Band 1 und 2. WILEY-VCH Verlag, Weinheim, 2000. • Bernecker, G.: Planung und Bau verfahrenstechnischer Anlagen. Springer Verlag, Berlin, 2001. Project Management: • Handout and publications, papers

Module 12 – Electives

Renewable Energy Systems – Environmental and Process Engineering	
Electives	
Module number	12
Module coordinator/ person responsible	Prof. Dr. T. Kampschulte
Duration of the module / semester / frequency	one or two semesters / 1st or/and 2nd semester / once or twice a year; depending on the selected courses
Credits (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	Contact hours: 72 h (typically, can vary with the selected courses) Self-study: 78 h (typically, can vary with the selected courses)
Type of module	Elective module
Module prerequisites **Requirements for participation / previous knowledge**	depends on the selected courses, see description of selected courses
Teaching language	English
Competencies gained / Learning Outcome	The idea of this module is that students can choose courses by interest from a range of electives offered aside of this master programme, published on the department's website, or from other master programmes when the content is related. The competencies gained and the learning outcome in particular are strongly depending on the selected courses and can be found in the description of these courses.
Content of the module	depends on the selected courses, see description of selected courses
Applicability of the module	depends on the selected courses, see description of selected courses
Requirements for the award of credit points **(Study and exam requirements)**	**Regular examination type for module testing:** depends on the selected courses, see description of selected courses. All types of exams which are defined in the general (APSO-INGI) or specific study regulations can be used. Where more than one possible examination type is used in the module, the examination type to be used is to be made known by the responsible lecturer at the start of the course.

Corresponding courses	Course 1: to be selected by the student Course 2: to be selected by the student Instead of selecting two courses with each less than 5 CP also one course of 5 CP can be chosen.
Learning and teaching types/ methods/ media types	depends on the selected courses, see description of selected courses. Mostly seminar-like lecture apply but can also be a seminar, a lab etc.
Literature	depends on the selected courses, see description of selected courses

Module 13 – Project Work

Renewable Energy Systems – Environmental and Process Engineering	
Project Work	
Module number	13
Module coordinator/ person responsible	Prof. Dr. T. Kampschulte
Duration of the module / semester / frequency	one semester / 1st or 2nd semester / every semester
Credits (CP) / semester hours per week (SHW)	5 CP / - SHW (individual project meetings)
Workload	Contact hours: 30 h Self-study: 120 h
Type of module	Elective module
Module prerequisites **Requirements for participation / previous knowledge**	none
Teaching language	English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** • The students acquire profound knowledge on the topic of their project. **Methodological competency (use, application and generation of knowledge)** 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. **Social competency (communication and cooperation)** The students are able to.... • perform the given task self consistent as a part of a team in a scientific manner, • identify and to define possible interfaces in interdisciplinary projects, • conclude and to present the results of the scientific work in a presentation and a report.

	Self-competency (scientific self-image, professionalism) The students are able to… • develop their own point of view and present it to the group. • organize themselves within a given timeframe. • elaborate and present a report on an academic level
Content of the module	Specific projects can be executed related to the scientific work done currently at the Faculty of Life Sciences of the Hamburg University of Applied Science in the field of renewable energy systems
Applicability of the module	This module can be used as preparation for the master thesis as similar skills are trained.
Requirements for the award of credit points **(Study and exam requirements)**	**Regular examination type for module testing:** project (SL)
Corresponding courses	Project work
Learning and teaching types/ methods/ media types	The project is an interdisciplinary class with individual tasks and overarching outcomes. Students work independently and as a group with the assistance of the member of teaching staff, and gain experience in literature research, discussion, presentation and/or practical work.
Literature	depends on the content of the project work

Module 14 – Energy Practice

Renewable Energy Systems – Environmental and Process Engineering	
Energy Practice	
Module number	14
Module coordinator/ person responsible	Prof. Dr. T. Kampschulte
Duration of the module / semester / frequency	one semester / 2nd semester / once a year
Credits (CP) / semester hours per week (SHW)	5 CP / 3 SHW
Workload	Contact hours: 54 h Self-study: 96 h
Type of module	Compulsory module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: basics from solar energy, biofuels, fuel cells, electrical engineering, lab work in general
Teaching language	English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** The students are able to.... • describe the experimental set up of testing stands for renewable energy systems. • explain experimental measurements. • define requirements to be kept in experiments. **Methodological competency (use, application and generation of knowledge)** The students are able to.... • combine knowledge of different subjects systematically, • acquaint themselves with new content in a systematic way, • transfer theoretical knowledge to application, • interconnect and operate different technical devices of renewable energy generators in the laboratory, • execute experiments in the laboratory, • apply and to develop suitable methods to analyse experimental results, • document measurements in technical reports. **Social competency (communication and cooperation)**

	The students are able to.... • work in a team and to take responsibility in teamwork, • cope with complex technical tasks independently, • organize experimental work, • discuss practical and theoretical aspects of the experiments within their peer group and with the supervisor. **Self-competency (scientific self-image, professionalism)** The students are able to… • develop and defend their own point of view and present it to the group. • organize preparation time and the follow up of reports
Content of the module	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 • …
Applicability of the module	The content of this module is related to module 3, 4, 5, 6, 7, 8 and 9. The practical learning in the lab is a preparation for the master thesis, in particular when lab work and experiments are part of the master thesis.
Requirements for the award of credit points **(Study and exam requirements)**	**Regular examination type for module testing:** Lab work completion (SL). Students have to prepare and execute 6 experiments and have to hand in lab reports. Experiments start with a colloquium to summarize the students' preparations.
Corresponding courses	Energy Practice Lab
Learning and teaching types/ methods/ media types	Lab work in small teams, technical reports, presentation of results
Literature	• Lecture notes of related modules • Lab instructions (for Energy Practice) • Technical manuals (for Energy Practice) • Literature of the related lectures (for Energy Practice)

Module 15 – Energy Policy and Finance

Renewable Energy Systems – Environmental and Process Engineering	
Energy Policy and Finance	
Module number	15
Module coordinator/ person responsible	Prof. Dr.-Ing. Hans Schäfers
Duration of the module / semester / frequency	One semester / 2nd semester / every academic year
Credits (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	Contact hours: 72 h Self-study: 78 h
Type of module	Compulsory module
Module prerequisites **Requirements for participation / previous knowledge**	None
Teaching language	English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** The students are able to.... • comprehend the rationale for using project financing • recognize the key characteristics of a robust project and identify weaknesses of a proposed structure • comprehend essential credit issues in assessing project finance proposals, • understand the mechanisms of international energy and climate policy • describe the gobal risks of climate change • evaluate energy policies of individual contries **Methodological competency (use, application and generation of knowledge)** By the end of this unit students are able to ... • 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, • interpret the risks identified and propose (contractual) mechanism to allocate these risks, • identify the various project funding sources available (equity/debt/mezzanine/bonds),

	• formulate, evaluate and select energy strategies to meet international expectations and requirements • understand the context and purpose of COP Meetings • understand the IPPC's workframe and relate to the IPCC's presentations on the global and regional risks of climate change • identify required content for the energy policy of individual contries according to the Paris Agreement (INDCs/NDCs) • recognize flexibility mechanisms (e.g. ETS / JI / CDM) **Social competency (communication and cooperation)** The students are able to.... • work autonomously on a task within a team and present it in the group. • critically reflect official political stand points on energy policies **Self-competency (scientific self-image, professionalism)** 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, • critically evaluate energy policies • understand the role, context and purpose of financial, energy and strategic management techniques. • specify and balance their own strong points and weak points in relation to their studies.
Content of the module	**Project Finance** • 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 **Energy Policy** • World energy demand and outlook • Fossil fuels and greenhouse gas emissions • Climate change threats according to IPCC • UN Framework Convention on Climate Change and the Conferences of the parties (COPs) • The Paris Agreement

	• Flexibility mechanisms (ETS / JI / CDM) • INDCs/NDCs • Case Studies on individual nation's energy policies
Applicability of the module	The module finds application in context with plant engineering and project management (module 11). Energy policy serves as a foundation for the application of renewable energies (modules 3 to 5) as well as smart grids (module 7).
Requirements for the award of credit points **(Study and exam requirements)**	**Regular examination type for module testing:** written exam (SL). Further possible examination types: oral exam, oral presentation/paper, project, portfolio exam Where more than one possible examination type is used in the module, the examination type to be used is to be made known by the responsible lecturer at the start of the course.
Corresponding courses	Course 1: Project finance (2.5 CP, 2 SHW) Course 2: International Energy Policy (2.5 CP, 2 SHW)
Learning and teaching types/ methods/ media types	seminar-like teaching, e-learning, self-studies, group work, role play computer-based training phases, case studies
Literature	**Project Finance** Bodmer: Corporate and Project Finance Modelling: Theory and Practice, Wiley Gatti: Project Finance in Theory and Practice: Designing, Structuring, and Financing Private and Public Projects, AP Hoffmann: The Law and Business of International Project Finance, Cambridge University Press Raikar & Adamson: Renewable Energy Finance: Theory and Practice, AP Yescombe: Principles of Project Finance, AP **Energy Policy** Hamilton: Energy Policy Analysis: a conceptual framework, Sharpe Aklin Urpelainen: Renewables - The Politics of a Global Energy Transition, MIT Press Welsh: Europe's Energy Transition: Insights for Policy Making, AP Unnerstall: The German Energy Transition: Design, Implementation, Cost and Lessons, Springer Klein et al.: The Paris Climate Agreement: Analysis and Commentary. Oxford Le Quéré et al: Global Carbon Budget (https://www.earth-syst-sci-data.net/10/405/2018/essd-10-405-2018-discussion.html) IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

Module 16 – Master Thesis

Renewable Energy Systems – Environmental and Process Engineering	
Master Thesis	
Module number	16
Module coordinator/ person responsible	Prof. Dr. T. Kampschulte
Duration of the module / semester / frequency	one semester / 3rd semester/ every semester
Credits (CP) / semester hours per week (SHW)	30 CP / - SHW (supervision by individual meetings)
Workload	Contact hours: ca. 50 h (by individual meetings with the supervisors) Self-study: ca. 850 h
Type of module	Compulsory
Module prerequisites **Requirements for participation / previous knowledge**	More than 240 CP from previous courses/studies (This is given if the student enters the master programme with 210 CP from a bachelor degree and has acquired another 30 CP from the master programme.)
Teaching language	English (exceptions can be made by agreement with the student, the supervisors and on permission from the examination committee, if the institution or company, where the student is doing the master thesis, requires documents in the institution's / company's principal language.)
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** The students are able to.... • develop a deeper understanding and expert's knowledge of the specific topic of the master thesis. • take part in scientific discussion related to the specific topic of the master thesis. **Methodological competency (use, application and generation of knowledge)** The students are able to.... • analyze and to systemize complex scientific tasks in the field of renewable energy systems and related topics, • define relevant tasks out of complex problems with scientific methodical and analytical skills, • define the state of the art of the specific task by using international reports and literature including databases, • 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,

	• 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, • solve a given task problem based with efficient working skills and in an given time. **Social competency (communication and cooperation)** The students are able 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, • guide and to coordinate a possible team, to moderate and to solve possible conflicts of the team, • identify and to define possible interfaces in interdisciplinary projects, • conclude and to present the results of the scientific work in a presentation and a report.… **Self-competency (scientific self-image, professionalism)** The students are able to… • develop their own perspective on scientific problems • organize themselves and behave professional in an professional environment
Content of the module	Master Thesis: specific projects related to the scientific work done currently at the faculty life sciences of the Hamburg University of Applied Science or research institutions or companies working in the field of renewable energy systems and related topics
Applicability of the module	
Requirements for the award of credit points **(Study and exam requirements)**	**Regular examination type for module testing:** Master Thesis (PL) The duration of the master thesis is 6 months.
Corresponding courses	Master Thesis
Learning and teaching types/ methods/ media types	research, lab experiments, computer simulations, study of scientific papers, working in teams, depending on topic and the institution or company where the master thesis is hosted Meetings with supervisors, smaller presentations during the master thesis
Literature	depends strongly on the topic of the master thesis.