UNIVERSITY OF AGDER

Programme description

(approved by UiA's "studieutvalg" November 1., 2011, ST-sak 11/53)

PhD programme in Technology – specialization in Renewable Energy

PhD programme - 180 credits - 3 years – Grimstad

Educational requirements
To be admitted into the PhD programme the applicant must meet one of the following requirements to competence in renewable energy:

- Hold a master's degree in a relevant subject area from a Norwegian university or qualifications approved as equivalent.
- Have different educational qualifications and credentials at master's degree level which upon individual evaluation are approved as a basis for admission.
- Have an educational qualification from an institution abroad (full degree) which is equivalent to minimum 4 years in the Norwegian university system and which formally qualifies for admission to doctorate studies in the country where the degree was awarded. The Faculty determines the number of credits that the qualification corresponds to at the Faculty of Engineering and Science.
  Applicants with an education of less than 5 years must expect that additional requirements will be imposed upon them, and that they will only receive a conditional offer of admission.

As a general rule, the following should apply:

- The average grade for courses included in the bachelor's degree (or equivalent) should be C (or equivalent) or higher.
- The average grade for courses included in the master's degree (or equivalent) should be B (or equivalent) or higher.
- The master's thesis (or equivalent) should have the grade B (or equivalent) or higher.

In instances where the applicant's average grades are lower than required, the hosting research group at the Faculty of Engineering and Science must document the probability of the applicant being able to complete the PhD programme. In such an event, the Faculty of Engineering and Science may recommend extra requirements to be included in the basis for admission.

Competence in English is a requirement for all applicants to the PhD program. International students that are not exempt from the English language requirements pursuant to the guidelines of the Norwegian Agency for Quality Assurance in Education (NOKUT), must document this through one of the following tests with the stated results or better:

- TOEFL – Test of English as a Foreign Language med with a minimum score of 550 for the Paperbased Test (PBT), or 80 for the Internet-based Test (iBT)
- IELTS – International English Language Testing System, with the result of 6.0

Recommended previous knowledge
The course programme requires knowledge at the master's level in renewable energy. Applicants who lack such prior knowledge may be requested to compensate for this by attending relevant courses at the Faculty of Engineering and Science. Applicants with little or no training in research must be prepared for extra work to carry out the programme within 3 years.

General description of the programme
The doctoral programme is a research education. The main objective of the PhD programme is to ensure that the students attain a high level of scientific expertise in renewable energy. The PhD students will receive formal training and supervision, providing him/her with broad scientific knowledge and in-depth knowledge, and give them the ability to undertake their own independent research. The students attain scientific expertise through their independent research work leading to a scientific dissertation in renewable energy. The research work and dissertation must be of international standard.

The PhD degree is awarded on the basis of:

1. Approved completion of the coursework component
2. Scientific dissertation
3. Doctoral degree trials

The doctoral degree trials consist of a trial lecture on a prescribed topic and defence of the dissertation (disputation).

The coursework component (theoretical curriculum) should usually correspond to 30 credits, and never less than 30 credits. The coursework component is composed individually for each PhD student. The content of the coursework component, combined with the dissertation, must provide professional breadth and depth in the academic field in question.

The coursework component should usually consist of at least 20 credits based on technological courses or science subjects, and at least 5 credits on the theory and ethics of science.

The trial lecture on the prescribed topic comes in addition to the coursework component, as do active participation in the Faculty's Forum with 2-3 presentations.

The programme's structure
The courses included in the coursework component should be advanced courses taken at the University of Agder or other universities. At the Faculty of Engineering and Science the courses will usually be PhD courses (as opposed to master's level courses).

The Faculty offers the following PhD level courses in renewable energy:

Course Code	Course Title	Credits	Comments
EX-602	*Philosophy of Science*	5	Compulsory
ENE601	*Energy Conversion*	5	Compulsory

ENE602	*Energy Meteorology* or MA-622 *Partial Differential Equations* or MA-623 *Stochastic Systems*	5	Compulsory
ENE603	*Techniques for Characterising Materials for Energy Systems*	5	Elective
ENE604	*Advanced Photovoltaics*	10	Elective
ENE605	*Electromagnetic Modelling*	5	Elective
ENE606	*Biomass and Bioenergy*	5	Elective
ENE701	*Advanced Statistical Methods for Renewable System Analysis*	5	Elective
ENE702	*Rural Electrification*	5	Elective
ENE703	*Fuel Cell Design*	5	Elective
ENE704	*Wind Turbine Systems*	5	Elective
ENE705	*Selected Topics in Renewable Energy*	5	Elective

The courses ENE601 and ENE602 form the multi-disciplinary common core material and will normally be included in the coursework component of the PhD students in renewable energy. However, for some PhD students the course ENE602 can be replaced by one of the mathematics courses MA-622 *Partial Differential Equations* or MA-623 *Stochastic Systems* if that is relevant to the research project. The course EX-602 is also compulsory.

The courses ENE701, ENE702, ENE703, ENE704 and ENE705 are based on the common core and form the specialist foundation in the coursework component. Normally, two or three of these courses will be included in the coursework component of each PhD student. In the selection of specialist courses it must be considered that, together with the research work, the student should gain the required multi-disciplinary and specialist skills for the PhD education.

Specialised courses at other universities or university colleges may be included as electives in the coursework component. Relevant PhD courses may be found for example at Aalborg University and Telemark University College.

Up to 10 credits of the elective courses may be taken as national or international research courses or through a special syllabus in the form of literature, or as methodological studies which are relevant to the research programme.

The research course should be evaluated by the Faculty of Engineering and Science with regard to extent and academic level. The following norm should apply: 25-30 hours student input are credited with 1 credit (following recommendations by the European Credit Transfer System – ECTS). In order to have a research course approved, the student must hold a seminar following completion of the course. The seminar should be evaluated by an examiner

appointed by the Faculty. Exceptions can be made for research training courses which are offered regularly at other universities and which have a final examination.

Courses taken in the form of special syllabus are to be described in an appropriate form where the content, level and extent correspond to other course descriptions as given on the Faculty's web pages. The type of examination must be stated. The description of the syllabus must be approved by the Faculty of Engineering and Science prior to the examination.

The Faculty credits research courses and special curricula with credits in whole units only.

The coursework component must be successfully completed and passed in its entirety before the student can apply to the Faculty to have the dissertation assessed.

Learning outcomes
Upon completion of the PhD programme, the students should have scientific competence at highest level in renewable energy. The students shall have acquired multi-disciplinary competence in renewable energy as well as specialist competence in at least one of the following areas:

- Photovoltaic technology and application
- Wind energy technology and application
- Fuel cells technology and application
- Power electronics in the context of energy conversion
- Bioenergy conversion

The students will be able to conduct independent research in renewable energy and to independently evaluate and assess other researchers' work in the subject area. Graduate candidates shall be qualified for research activities and other types of work in which a high degree of academic expertise and scientific competence is required.

Teaching methods
The PhD programme is a three-year full-time study programme. Plans for completion of the PhD programme over a period longer than 6 (six) years will not be approved.

The PhD programme is a research education consisting of a coursework component of at least 30 credits and a research project, the doctoral dissertation, which amounts to 150 credits (2,5 years of work). The dissertation is prepared under the supervision of two highly qualified scientists.

The teaching methods in the coursework component appear from the course descriptions. In the event of several courses being offered in the same semester, the teaching arrangement will be coordinated.

The courses will normally be taught in English.

Evaluation methods
All courses or other activities to be included in the coursework component must have a final evaluation. Most courses are concluded with an oral examination, possibly in combination with a project report or an essay. The evaluation method in the courses appears in the course descriptions.

Grading: Pass/Fail, where Pass corresponds to the grade B or higher.

The doctoral programme concludes with a trial lecture on a prescribed topic and a public defence (disputation) where the candidate gives an account of the results of the scientific investigations in the dissertation, etc. The disputation is further described in the supplementary regulations for the PhD Degree in Technology at the University of Agder.

Student exchange
All PhD students with previous education from Norway should include a stay at a foreign university with a recognized research environment within the research field of the individual student. The stay may be of 3-6 months duration, preferably at an institution recommended by the supervisors.

Research will be the main goal of the stay abroad, but additionally, PhD students may complete some of their courses at the foreign institution. Passed examinations in courses completed abroad can substitute corresponding mandatory and specialisation courses in the course programme and thus form part of the coursework component. In addition, credits may be awarded for research training courses etc. completed abroad, as described above.

Professional goal and access to further studies
The PhD programme is the highest education in the country, and provides qualifications required for university and college appointments at the associate professor level. Alternative career paths are found in research institutes, as well as research departments in industry and business, and other types of work in which a high degree of academic expertise is required.

Qualification awarded
Philosophiae doctor (PhD) in Technology with specialization in Renewable Energy

Responsible Faculty
Faculty of Engineering and Science

Contact person
For additional information, please contact the scientific administrator of the programme, associate Professor Henrik Kofoed Nielsen.

Courses PhD Programme - Renewable Energy

General courses

ENE601/MAS704 Energy Conversion

5 credits – Grimstad

Study programme
PhD programme in Technology – specialization in Renewable Energy and Mechatronics

Learning outcomes
After the course is completed, the students will have an overview of the relevant types of energy conversion principles. Furthermore, the students will know about some of the current research topics and research methodology within this field.

Contents
The course will contain selected topics from the following list:

- Principal Fuels for Energy Conversion
- Production of Thermal Energy
- Fossil-Fuel Systems
- Nuclear Reactor Design and Operation
- Environmental Impact of Power Plant Operation
- Production of Mechanical Energy
- Production of Electrical Energy
- Energy Storage
- Solar and Wind Energy

Teaching methods
Lectures, exercises

Examination
Oral examination. Pass/Fail

Offered as a free-standing course
Yes

Responsible faculty
Faculty of Engineering and Science

ENE602 Energy Meteorology

5 credits – Grimstad

Study programme
PhD programme in Technology – specialization in Renewable Energy

Learning outcomes
The learning outcome of the course is insight into current research topics in energy meteorology.
The successful candidate will have knowledge of the state-of-the-art within a number of topics related to the acquisition of information on the spatial and temporal characteristics of the meteorological fields with relevance to renewable energy application.
The successful candidate will have knowledge of the state-of-the-art within a number of topics related to the modelling of the meteorological fields with relevance to renewable energy application.

Contents
The course presents a number of selected topics within state-of-the-art energy meteorology. Emphasis is on both advanced methods for the data acquisition of the fields on solar irradiance and wind speed and methods for the modelling of the respective fields. The course will contain selected topics from the following list:

- Radiative transfer in the atmosphere
- Remote sensing of the atmosphere
- Derivation of irradiance data from satellite information
- Advanced methods for wind measurements, both local (e.g. ultrasonic) and remotely (Sodar and Lidar)
- Mesoscale and microscale modelling of wind fields

Teaching methods
Lectures, exercises, supervision of a short seminar talk

Examination
Essay and oral examination. Pass/Fail

Offered as a free-standing course
Yes

Responsible faculty
Faculty of Engineering and Science

ENE603 Techniques for Characterising Materials for Energy Systems

5 credits – Grimstad

Study programme
PhD programme in Technology – specialization in Renewable energy

Learning outcomes
The student will gain practical hands-on experience in the chosen techniques, including sample preparation, image processing and data analysis. Specimens relevant to the PhD project will be selected for study and the results incorporated in the PhD thesis.

Contents
The course will cover research level laboratory techniques including optical and electron microscopy, sample preparation, image analysis and interpretation. Electron microscopy will involve use of the scanning electron microscope (SEM). Scanning Tunnelling Microscopy (STM) will also be optional.

Electrical measurements will include 2-wire and 4-wire methods and the use of AC impedance spectroscopy. The student can select particular methods relevant to the PhD project for in-depth study.

Teaching methods
Laboratory supervision and demonstration of chosen experimental methods

Examination
Oral examination. Pass/Fail

Offered as a free-standing course
Yes

Responsible faculty
Faculty of Engineering and Science

ENE604 Advanced Photovoltaics

10 credits - Grimstad

Study programme
PhD programme in Technology – specialization in Renewable Energy

Recommended previous knowledge
ENE501 Photovoltaic Technology or equivalent

Learning outcomes
The course will give the students an advanced understanding of photovoltaic conversion principles from photons to electricity. Some selected topics will be discussed in the context of current research.
After this course the student will be able to do solar cell research work in selected areas under supervision. The student will be able to analyze theoretical problems and apply results to experimental studies.
After this course the student will be able to present advanced concepts in a professional manner.

Contents
The course will contain selected topics from the following list:

- Electrons and holes in semiconductors
- Generation and Recombination
- Junctions
- Monocrystalline Solar Cells
- Thin Film Solar Cells
- Energy, Entropy and Efficiency
- Tandem Cells
- Hot Carrier Cells
- Up- and down-conversion
- Multiple Electron-Hole Pairs, Impurity and Multiband Cells
- Thermophotovoltaic and Thermophotonic Conversion
- Strategies for high Efficiency

Teaching methods
Lectures, exercises

Examination
Oral examination. Pass/Fail

Offered as a free-standing course
Yes

Responsible faculty
Faculty of Engineering and Science

ENE605/MAS702 Electromagnetic Modelling

5 credits – Grimstad

Study programme
PhD programme in Technology – specialization in Renewable Energy and Mechatronics

Learning outcomes
After completing the course, the successful student will have a sufficient understanding of generalized theory of AC electrical machines (dq-theory), enabling them to apply these principles in advanced control of induction motor drives; and have a sufficient understanding of mathematical formulations for static and quasistatic electromagnetic field problems, enabling them to apply these principles in analysis and design of certain mechatronic system components.

Contents
Part 1: Advanced modelling of electrical machines. Space vectors, dq-theory and vector control of induction motor drives.
Part 2: Short review of Maxwell's equations. Formulations and solutions for selected static and quasistatic electromagnetic field problems.

Teaching methods
Lectures, exercises and project work (individual or groups of 2-3 students)

Examination
Project report, oral examination. Pass/Fail

Offered as a free-standing course
Yes

Responsible faculty
Faculty of Engineering and Science

ENE606 Biomass and Bioenergy

5 credits - Grimstad

Study programme

PhD programme in Technology – specialization in Renewable Energy

Learning outcomes

After completing the course, the successful student will have a sufficient understanding of the principles and limitations behind biomass for energy applications. The student will achieve a deeper knowledge about the interaction between biomass and its use for energy applications, and be able to select relevant biomass fuel properties for modelling purposes.

Content

Physical and chemical characterisation of biomass resources as feedstock and fuel.
Biomass from energy crops and algae.
Biomass handling and storage.
Biomass conversion technologies for production of biofuels (solid, liquid and gaseous).

Teaching methods

Lectures and practicals

Examination

Essay and oral examination. Pass/fail

Offered as a free-standing course

Yes

Responsible faculty

Faculty of Engineering and Science

Specialization courses

ENE701 Advanced Statistical Methods for Renewable System Analysis

5 credits – Grimstad

Study programme
PhD programme in Technology – specialization in Renewable Energy

Recommended previous knowledge
ENE602 Energy Meteorology

Learning outcomes
The learning outcome of the course is gaining knowledge on statistical methods to be applied for the assessment and the operation of renewable energy systems. The successful candidate will be capable of applying advanced statistical methods for the characterisation of meteorological field, and the syntheses of field for simulation studies.

Contents
The course presents a number of selected topics within state-of-the-art energy meteorology. Emphasis is on both advanced methods for the data acquisition of the fields on solar irradiance and wind speed and methods for the modelling of the respective fields.
The course will contain selected topics from the following list:

- Methods for the statistical characterisation of spatial-temporal fields
- Linear and non-linear methods for the synthesis of stochastic fields
- Application of reservoir theory to renewable energy systems
- Multicriterial methods for the quality assessment of simulation models

Teaching methods
Lectures, exercises, supervision of a short seminar talk

Examination
Oral examination. Pass/Fail

Offered as a free-standing course
Yes

Responsible faculty
Faculty of Engineering and Science

ENE702 Rural Electrification

5 credits – Grimstad

Study programme
PhD programme in Technology – specialization in Renewable Energy

Recommended previous knowledge
ENE601 Energy Conversion

Learning outcomes
The learning outcome of the course is gaining an insight in the application of renewable energy technologies for the development of rural regions in less developed or emergent economies. Students should know about methodologies for the assessment of the actual energy need and its future change in regions up to now not connected to central supply networks. They know about technical and non-technical criteria and methods to rank different technical options and are able to perform the respective selection.

Contents
The course content will on the one hand deal with the assessment of the basic energy needs and their fulfilment by analysing and discussing the theoretical studies and reports on respective projects. On the other hand, an extended case study should be performed by the students.

Teaching methods
Lectures, supervised and extended case study and a talk reporting on its outcome

Examination
Evaluation of the case study report and presentation. Pass/Fail

Offered as a free-standing course
Yes

Responsible faculty
Faculty of Engineering and Science

ENE703 Fuel Cell Design

5 credits – Grimstad

Study programme
PhD programme in Technology – specialization in Renewable Energy

Recommended previous knowledge
ENE601 Energy Conversion

Learning outcomes
The student will gain an in-depth knowledge of fuel cells and fuel cell systems, including aspects of recent trends and sate-of-the –art innovations. The student will learn to design and produce components using in-house rapid prototyping tools. The student will gain practical training in testing fuel cell stacks and determining performance characteristics. The course will bring together both engineering and scientific disciplines.

Contents
The course is focused on fuel cell design encompassing fuel cell systems, fuel processing, heat and water management and stack issues. The course will be largely based on laboratory and workshop practices. Practical work will be augmented by lectures and demonstrations. The student will be expected to read literature articles and be familiar with "SolidWorks" design tools. The student will choose a design topic and produce a written report.

Teaching methods
The course will comprise lectures, demonstration and practical work. The student will select the design topic and produce a written report for the examination.

Examination
Oral examination including assessment of the design topic and report. Pass/Fail

Offered as a free-standing course
Yes

Responsible faculty
Faculty of Engineering and Science

ENE704 Wind Turbine Systems

5 credits - Grimstad

Study program
PhD programme in Technology – specialization in Renewable Energy

Recommended previous knowledge
ENE601 Energy Conversion and ENE602 Energy Meteorology

Learning outcome
The learning outcome of the course is insight in to the configuration of wind turbine systems by appropriate match of rotor characteristics, generator characteristics and control strategy.
The successful candidate will have knowledge of the state-of-the-art of wind turbine systems design.
The successful candidate will have knowledge of operational characteristics of differently designed systems in view of their integration into energy supply systems.

Contents
The course presents a number of selected topics within state-of-the-art turbine design. Emphasis is on the match of the aerodynamic properties of the rotor and the electromechanical properties of generator. The course will contain selected topics from the following list:

- rotor design in view of optimal efficiency versus robust operational characteristics
- generator concepts for variable speed operation
- grid interference of difference of different rotor/generator concepts

Teaching
Lectures. exercises (7 days), supervision of a short seminar talk

Examination
Oral examination. Pass/Fail

Offered as a free-standing course
Yes

Responsible faculty
Faculty of Engineering and Science

ENE705 Selected Topics in Renewable Energy (self study course)

5 credits – Grimstad

Study programme

PhD programme in Technology – specialization in Renewable Energy

Learning outcomes

The course is designed to give the student experience in interpreting literature and journal sources as background for articles relevant to the chosen PhD topic. The task is very focused on producing a succinct and clear review of the state-of-the-art in the chosen subject and serves as a foundation for the literature survey required for the PhD thesis.

Contents

The self study course will require the student to carry out a full literature research relevant to the selected PhD project. A written report of at least 20 pages will be expected. The report will disseminate and critique the found publications and will show the relevance of the information to the selected PhD topic. The report will form the basis for the examination.

Teaching methods

Supervision will be given on the method for searching the literature and scope of the selected topic. The report will be reviewed by the supervisor for accuracy and relevance before the oral examination.

Examination

An oral examination of the written report, testing the candidate's knowledge of the chosen subject. Pass/Fail

Offered as a free-standing course

Yes

Responsible faculty

Faculty of Engineering and Science

Literature list

EX-602 Philosophy of Science (reading list 2010)

- Chalmers, A. F.: *What is this thing called Science?* (3rd or 2nd ed.) Buckingham: Open University Press 1999.
- Gallagher, S. & D. Zahavi: *The Phenomenological Mind*. Chapter 2: *Methodologies.* London & New York: Routledge 2008.
- Weyl, H.: *Space Time Matter*. (4th ed.) *Introduction*. Transl: H. M. Brose. New York: Dover Publications (1952). Original: *Raum Zeit Materie*. Berlin 1918.
- Wittgenstein, L.: *A Lecture on Ethics.* The Philosophical Review, **74** 1, 1965.
- Nilsen, T. V.: *Ecophilosophy and Ethics*. Lecture Notes 2010.
- Resnik, D. B.: *What is Ethics in Research & Why is It Important?* National Institute of Environmental Health Sciences: http://www.niehs.nih.gov/research/resources/bioethics/whatis.cfm
- *Social Theory.* New World Ecyclopedia. http://www.newworldencyclopedia.org/entry/Social_theory

ENE601 Energy Conversion

- Culp, A.W., Jr., "Principles of Energy Conversion", pp. 43-496
- Course specific notes and selected scientific papers

ENE602 Energy Meteorology

- Energy Meterorology, Detlev Heinemann, Lecture Notes, University of Oldenburg http://www.energiemeteorologie.de/team/dehe/Documents/Energy_Meteorology__%20Script.pdf
- Solar Energy Resource Management for Electricity Generation E. D. Dunlop, L.Wold, Marcel Suri (eds), Nova Science Publishers, Inc. (2006) ISBN 1-59454-919-2
- Spatial and Temporal Variability in Solar Radiation, A. Hammer and H.G. Beyer, in: Encyclopedia of Sustainability Science and Technology, C. Gueymard ed., Springer 2011
- Solar Energy: Research, Technology and Applications, Editors: William L. Olofsson and Viktor I. Bengtson, Nova Science Publishers, Hauppauge NY (USA), ISBN: 978-1-60456-739-7 (2008)
- Course specific notes and selected scientific papers

ENE604 Advanced Photovoltaics

- Course specific notes and selected scientific papers

ENE605 Electromagnetic Modelling

- Mohan, "Advanced electric drives", MNPERE 2001
- Lecture notes and selected papers

ENE606 Biomass and bio energy

- Lo & Koppejan (2008): The handbook of Biomass combustion & co-firing. Earthscan. ISBN 9781844072491
- Bassam (2010): Handbook of bioenergy crops, a complete reference to species, development and applications. Earthscan 9781844078547
- Ayhan Demirbas (2009): Biofuels Securing the Planet's Future Energy Needs. Springer. ISBN 978-1-84996-814-0
- Selected scientific papers

ENE701 Advanced Statistical Methods for Renewable System Analysis

- Methods and Applications of Statistics in Engineering, Quality Control, and the Physical Sciences, N. Balakrishnan, Campbell B. Read, Brani Vidakovic, Samuel Kotz, Norman L. Johnson, Wiley (March 8, 2011), ISBN-13: 978-0470405086
- Wind Energy: Proceedings of the Euromech Colloquium, Joachim Peinke, Peter Schaumann, Stephan Barth, Springer (2010)
- Space and time statistics of wind and solar radiation fields and its application to renewable energy system analyses – a contribution to energy meteorology, H.G. Beyer, Habilitation Thesis, University of Oldenburg (1994)
- Course specific notes and selected scientific papers

ENE702 Rural electrification

- Renewables and Rural Electrification, edi.: G.Chakravarthy, A. Shukla and A. Misra, Bibliotheks- und Informationssystem der Carl von Ossietzky Universität Oldenburg (BIS)-Verlag, ISBN: 3-8142-0928-1 (2004)
- Course specific notes and selected scientific papers

ENE703 Fuel Cell Design

- Fuel Cell Systems Explained, James Larminie and Andrew Dicks
  Wiley, 2nd edition, ISBN 0-470-84857

ENE704 Wind Turbine Systems

- Wind Energy Explained: Theory, Design and Application by James F. Manwell, Jon G. McGowan and Anthony L. Rogers. Wiley; 2nd edition (February 23, 2010), 0470015004ISBN

- Aerodynamics of Wind Turbines by Martin O. L. Hansen, Routledge; 2nd edition (December 20, 2007), ISBN 1844074382

- Wind Energy Generation: Modelling and Control by Olimpo Anaya-Lara, Nick Jenkins, Janaka Ekanayake and Phill Cartwright. Wiley; 1st edition (September 23, 2009), ISBN 0470714336

- selected journal articles