Study programme in Sustainable Energy Systems

Knowledge and understanding
Upon completion of the study programme the student shall:

- demonstrate knowledge and understanding within the disciplinary domain of Energy Engineering, comprising both broad general knowledge in the field and significantly specialised knowledge in specific subareas, as well as greater insight into current research and development work, and also

- demonstrate in-depth methodological knowledge within the disciplinary domain of Energy Engineering.

Skills and abilities
Upon completion of the study programme, the student shall:

- demonstrate the ability to integrate knowledge critically and systematically, and to analyse, assess and handle complex phenomena, problems and situations, even if information is limited,

- demonstrate the ability to identify and formulate problematic issues critically, independently and creatively, to plan and solve advanced tasks with adequate methods and within stipulated time frames, thereby contributing to the development of knowledge, and to evaluate this work,

- demonstrate the ability to present and discuss, in both national and international contexts, both orally and in writing, conclusions along with the knowledge and arguments on which they are based, in dialogue with different groups, and

- demonstrate the necessary skills required for participating in research and development work or for working independently in other advanced contexts.

Critical judgement and approach
Upon completion of the study programme, the student shall:

- demonstrate the ability, within the disciplinary domain of Energy Engineering, to make assessments with respect to relevant scientific, societal and ethical aspects, and to be aware of ethical aspects in research and development work;

- demonstrate insight into the possibilities and limitations of science, its role in society, and people’s responsibility for how it is put to use, and

- demonstrate the ability to identify the need for additional knowledge and to take responsibility for his/her own knowledge development.

Eligibility
A completed Bachelor’s degree from an institution of higher education of three years or more, equivalent to at least 180 credits and with a major in engineering, including Engineering thermodynamics, Heat transfer/Thermal engineering and Fluid dynamics and at least 22,5 credits Mathematics/Applied Mathematics.
A TOEFL test result, with a minimum score 575 with a TWE score of at least 4.5 (PBT) or 90 with a TWE score of at least 20 (iBT), or an IELTS test result with an overall band score of at least 6.5 and no band score below 5.5, or equivalent is required.

Course package

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Overall course descriptions

**INTRODUCTION TO SUSTAINABLE ENERGY SYSTEMS**
The course Introduction to Sustainable Energy Systems is designed to improve the participants’ understanding on energy systems. In this course different methods of producing heat and power are discussed. Calculations on the efficiency and power output of energy processes and components as well as economical optimisation are performed. Moreover this course will introduce the student in the scientific method, to provide them with the necessary tools to properly document their work.

**INTERNATIONAL ENERGY SYSTEMS**
The main purpose of the course International Energy Systems is to define the concept of an energy system and how sustainable energy systems can be used together. Examples of the development of energy systems at global, national, regional and local level are given. Studies on the scientific, technical and economic aspects that affect the different energy systems are carried out. The main actors within the energy sector as well as the controlling policies are included.

**PROCESS SIMULATION, MODELLING AND OPTIMISATION**
The overall aim of the Process Modelling course is to provide an understanding of methods and techniques and tools for modelling energy processes. Analytical, numerical and statistical methods
are discussed, as well as discretization techniques. In the course Process Simulation different simulation tools within the energy engineering field will be discussed. The major topics covered are simulation and validation, input data modelling and output data analysis. In the course Process Optimisation, theories behind optimisation and practical optimisation problems in the energy area are solved. Dynamic optimisation problems of energy conversion systems are solved with computational algorithms based on linear programming, geometric programming and dynamic programming. The course also deals with economic investment methods and operation optimisation from an economical perspective.

**Detailed course descriptions**

**Introduction to Sustainable Energy Systems, 7, 5 credits**

**Objectives**
The course aims to provide participants with a deeper understanding of the possibilities and limitations of future energy systems. The course will also provide knowledge of the technology and systems used to convert the energy contained in a fuel into heat and electricity. The course will also provide knowledge about how energy from the sun and wind can be used to generate electricity. One should after the course be familiar with the function of the components in different energy systems and carry out dimensioning of these. The course aims to develop the student's individual abilities regarding written presentations, information seeking, critical analysis of information, literature and other materials.

**Learning objectives**
After completing the course students will be able

- Apply methods to analyse complex energy

- Describe and apply the concept of sustainable development to such an extent that an analysis can be made of various strategies for sustainable energy with regard to the ecological, economic and social aspects

- Thoroughly explain and illustrate advanced concepts in energy

- Have some knowledge of research and development in sustainable energy

- Describe the principle of converting solar energy, wind energy and bio-energy to different forms of energy

- Demonstrate broad knowledge and perform calculations in solar and wind power

- Describing the combustion process and calculate the flue gas composition, flue gas and boiler efficiency

- Use thermodynamic relations and equations to calculate and analyse various types of power / thermal processes for finance, technology and environment

- Describe principles for different types of power and heat generation and the components that occur in power and heating plants
Course content
This course provides basic knowledge on issues related to society's energy and sustainable development. The course covers various fuels, the combustion process and the emissions produced during combustion. The course covers various combustion facilities and technical equipment used in gas. The course includes review of thermodynamic cycles for the conversion of heat into mechanical energy, steam cycle with heat from various fuels, gas turbine cycle and energy conversion in turbo machinery. The course provides an overview of solar and wind power with respect to technology, environment, economics, problems and opportunities.

International Energy Systems, 7, 5 credits
The course will provide knowledge about resources, conversion and use of energy from a system perspective. The course will provide an understanding and practical application of theories and models for the development of energy systems in the world. Develop the student's individual abilities regarding: written presentations, information seeking, critical analysis of information, literature and other material in a scientific manner.

Learning objectives
After completing the course students will be able

- Demonstrate knowledge of the stakeholders that are important for the development of the energy system and how science (e.g. geoscientific and ecological), technological, economic and political conditions affecting the conditions for and the development of energy systems Critically analyse and interpret a country's energy system (construction, actors, scientific, technological, economic and political conditions)

- Discuss and analyse the possible development of a country's energy system to promote sustainable development

- Demonstrate the ability to integrate knowledge and handle complex information on policies and policy instruments, different players, trends, costs, climate and environmental resources for energy

- Independently conduct a study on energy

- Demonstrate an ability to clearly communicate and present the conclusions and methods of its own investigation of energy

- Written and oral presentation of results from a separate study on energy in a scientific manner.

Course content
The course covers definitions of systems and energy systems and what systems thinking, building and development of energy systems in the world does. Here are examples from different parts of the world, describing the actors in the energy sector at the global, national, regional and local level, description and discussion of science (e.g. geo-scientific and ecological), technological, economic and political conditions that affect energy systems, instruments and development in the energy sector as well as local conditions for energy.
Process Modelling, 7, 5 credits

Objectives
The course will give deeper knowledge in mathematical modelling of energy processes.

Learning objectives
After completion of the course the student shall be able to:

- identify the assumptions, equations and boundary conditions necessary for model building
- define setup, analyse and test models within process engineering
- apply conservation principles and develop constitutive relations used for modelling purposes
- select and utilize appropriate numerical methods to solve steady state and dynamic models
- encode models in suitable programming languages
- understand and apply the most commonly used methods in statistical model calibration and validation
- show knowledge within the research area of process modelling

Course content
The course covers principles in model building in process engineering, theory about mathematical modelling within energy processes, analytical and numerical solutions, statistical and empirical modelling

Process Optimization, 7, 5 credits

Objectives
The course will give deeper theoretical knowledge in the field of mathematical optimization of energy related processes.

Learning objectives
After completion of the course the student shall be able to:

- identify and set up functions describing an optimization problem in energy related processes
- choose a mathematical method for solving the developed equations
- use computer programs for solving optimization problems
- evaluate results derived from the solution of an optimization problem

Course content
The theoretical background about setting up objective functions and constraints for energy related processes. Mathematical optimization methods as Lagrange Multipliers method, dynamic programming, search methods, linear programming with and without binary variables. Economic
analyses and production planning in district heating systems. Practical use of computer programs for solving optimization problems.

Process Simulation, 7, 5 credits

Objectives
The course will give deeper knowledge in the use of simulation within energy processes.

Learning objectives
After completion of the course the student shall be able to
- understand the principles behind commercial simulation tools
- Select and use appropriate simulation tools for dynamic and steady-state simulations
- build and implement models in simulation tools for different applications related to the energy area
- validate simulation models towards real process data
- use models for different applications such as process optimization, system design, decision support and production planning
- analyse and critically review simulation results in relation to real process data
- show knowledge within the research area of process simulation

Course content
The course covers principles in building simulation models in process engineering, use of different tools for dynamic simulation, chemical equilibrium calculations and energy and material balances for different type of problems, simulation solvers, including simultaneous and sequential solvers, model verification and validation.

Numerical Methods with MATLAB, 7, 5 credits

Objectives
Numerical methods are used to solve mathematical problems by the help of computers. In economics and engineering different mathematical models are developed to analyse some interesting problems. These models are often very complex and involve a large number of variables and conditions. Different kinds of approximations can be used to solve such problems by a computer. This course focuses on some of the most important methods. The numerical software package MATLAB is introduced and used throughout the course. Basic algorithms and programming in MATLAB are included in the course.

Learning objectives
At the end of the course the student is expected to be able to
- construct and apply small programs in MATLAB to mathematical problems.
- solve non-linear equations, in particular using fix-point iteration methods.
- solve linear equation systems using Gaussian elimination and perform different kinds of matrix factorization (like LU-factorization).

- Approximate derivatives using difference quotient and central-difference formulas.

- construct Taylor polynomials for a given function and interpolation polynomials, like Lagrange and Newton polynomials, for a given set of points.

- use numerical methods (like the methods of Euler, Heun and Runge-Kutta) to solve differential equations.

- use numerical methods (like Simpson’s rule) to perform integration.

- carry out computational projects within numerical methods using MATLAB, to write structured reports and to perform oral presentations.

**Course content**
Introduction to MATLAB, basic algorithms in programming and programming in MATLAB. Numerical methods: non-linear equations, linear systems, interpolation, numerical differentiation, differential equations and numerical integration. Applications in economics.

**Applied matrix analysis, 7, 5 credits**

**Objectives**
The course provides broad knowledge of applications of matrices and of the essential tools of matrix analysis in various areas of engineering and natural sciences. The basic concepts and methods of importance for further study is explained with practical examples from finance, economics, statistics, discrete mathematics and related models from energy, environment and resource optimization, systems analysis, automatic control, computer science and information technology. In addition to training in logical and geometric thinking and the modelling and computing with matrices of particular importance for applications, as well as the capacity for independent analysis and solution of mathematical problems and models is trained.

**Learning objectives**
- After completing the course, students should be able to describe the basic properties of non-negative and stochastic matrices, their connection with graphs and Markov chains and applications in economics, resource optimization, information technology, linear and dynamic programming, decision making, game theory and systems analysis.

- calculate the matrix, canonical forms, functions of matrices and solutions of matrix equations and apply them in studies of system stability and in energy engineering.

- describe different types of matrix and vector norms, and calculate or estimate those with and without computer.

- explore and analyse iterative algorithms for calculating eigenvalues and eigenvectors for various types of matrices with and without computer.

- describe the properties of quadratic forms, projections, spectral theory and their use in quadratic optimization and variational principles and applications in statistics, finance and automatic control.
- analyse the matrix computations in geometrical terms of linear spaces, linear transformations and symmetries.

- explain the concepts within content of the course in a way that is appropriate for the recipient’s prior knowledge, and describe a handful of applications.

- describe in detail a freely chosen application area of matrix analysis.

**Course content**
Non-negative and stochastic matrices; matrix factorisations, canonical forms, matrix polynomials and matrix functions, matrix equations and system stability, spectral theory, projections, norms of matrices and vectors, scalar, singular values, quadratic forms, quadratic optimization and variational principles; iterative algorithms for matrices; matrix computations in terms of linear transformations and symmetries; applications of matrix analysis in engineering and natural sciences.

**Programming, 7.5 credits**

**Objectives**
The aim with this course is to give the students basic knowledge in programming with C# or other programming language.

Learning objectives

Upon successful completion of this course, the student will be able to:

- solve a problem by writing a C# program. The problem should be of such a type that the solution involves at least the following: iteration, selection, variables, methods with more than one argument and definition of at least one class.

- read code written with C#, and with her/his own words describe what problem the program is solving. This program should also include the following: iteration, selection, variables, methods with more than one argument and classes that is not from one of the standard libraries.

- document C# programs on both function and program level

**Course content**
Programming techniques: basic knowledge of structured programming. Problem solving strategies. Basic concepts from object oriented programming such as classes, methods and objects. The Programming language C#. Basic language elements such as data types, in- and output, sequences, selection, iteration, classes, methods, arrays and data structures.

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*More information about each course is available at:* [http://www.mdh.se/utbildning/kurser](http://www.mdh.se/utbildning/kurser)