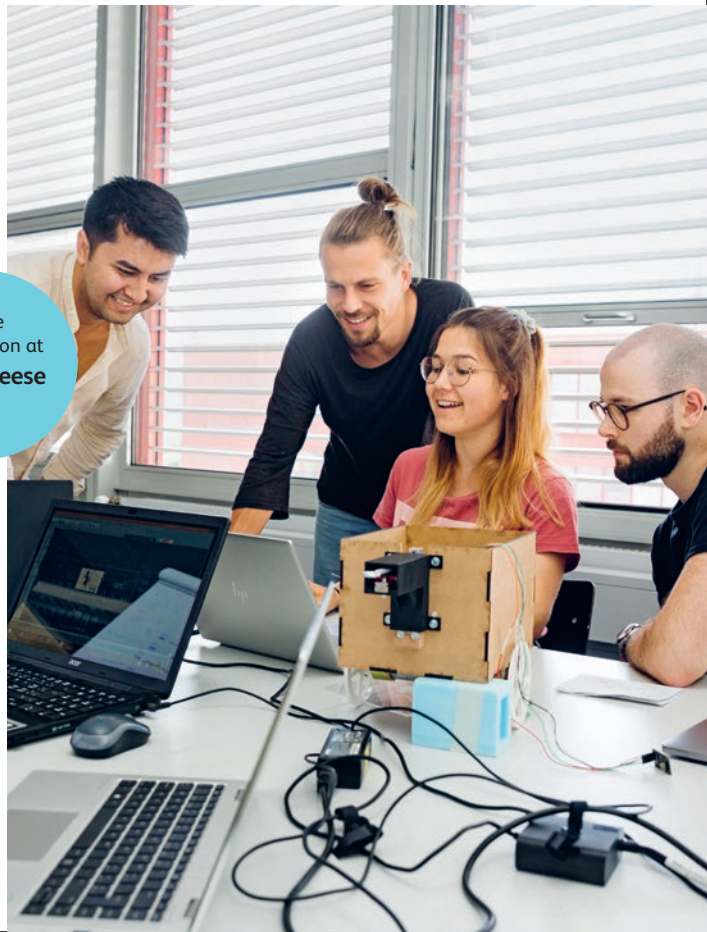


# Energy and Environmental Systems Engineering

Curriculum  
2023/2024

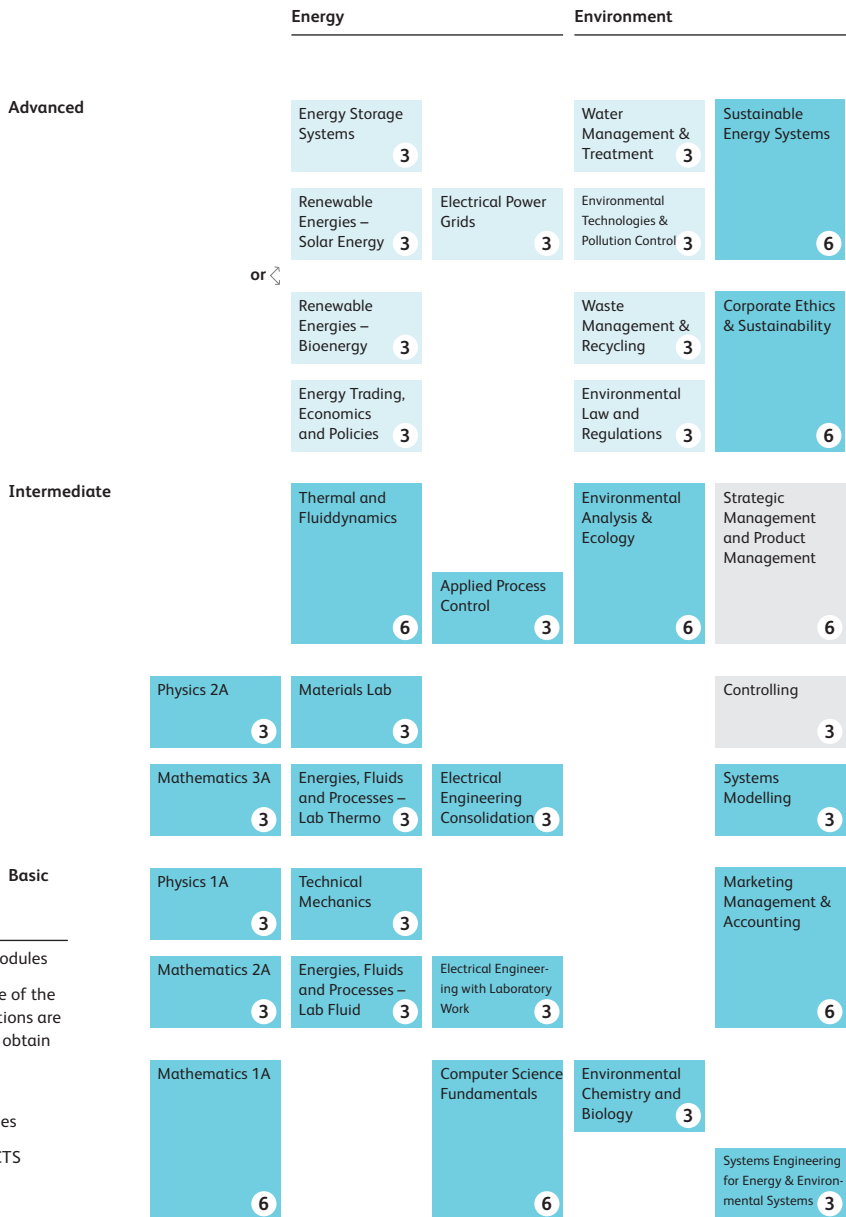
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# Structure of the Bachelor program

## Core modules

At least 90 ECTS credits are to be earned



- Compulsory modules
  - 12 ECTS of one of the two specializations are compulsory to obtain the respective specialization
  - Elective modules
- 6** Quantity of ECTS credits (here 6)

### Project modules

At least 39 ECTS credits are to be earned

### Related modules

At least 15 ECTS credits are to be earned

Bachelor Thesis

12

Industrial Project

6

Practical Modules

3/6

Practical Experience

3

International Project

6

Engineering Product Development Project 2

6

Engineering Product Development Project 1

6

Context 2

3

Context 1

6

Digital Business Models

3

New Business Development

3

Digital Business Process Engineering

3

Operational Excellence

3

Supply chain Management

3

Service Innovation

3

Sales Management

3

Energy Optimization with Pinch Analysis

3

Innovation Financing

3

Energy Data Analytics & Forecasting

3

Building Technology Systems

3

Leadership

3

Applied Machine Learning and Predictive Modeling

3

Design, build and commission Photovoltaic in Ethiopia

3

Basics of Electrical Drive Systems

3

Statistical Data Analysis 1

3

Usability

3

International Marketing

3

Statistical Data Analysis 2

3

B2B Marketing

3

Linear Algebra

3

Design Fundamentals

3

Windpower and Ecotechnology

3

Construction Physics for Building Technology

3

## Core modules – Compulsory

### Applied Process Control Compulsory E

The concepts of systems and signals will be elucidated. They will be characterized by means of the Laplace-Transformation. Students will get familiar with feedback loops and will learn to design controllers that guaranty stability and performances. Laboratories will help to consolidate the acquired knowledge.

### Computer Science Fundamentals Compulsory E

Introduction to computer science and the Internet, fundamentals of programming in Python, Internet of Things, databases, cloud-management, interconnecting computers, information systems in companies.

### Corporate Ethics and Sustainability Compulsory E

Fundamentals of Business Ethics (BE) and Corporate Responsibility (CR) for a practical use in different management positions. Students learn on the basis of case studies to get in contact with practitioners for exchange of experiences. Basic and well-grounded overview about BE/CR and central concepts, empirical situation, theoretical discussion and the implementation in management practice. Students will apply gained knowledge in energy-related simulation game allowing to experience real-world ethical challenges.

### Electrical Engineering with Laboratory Work Compulsory E

Fundamentals of electrostatics, direct current, magnetic fields, and alternating current. Become acquainted with key components and systems through laboratory experiments.

### Electrical Engineering Consolidation Compulsory E

Consolidation of basic applications: due to enhanced mathematic skills it is possible to formulate and understand more realistic models. Analysis of meshed linear circuits for direct current and sinusoidal alternative current. Investigation of non-linear behaviour by analysing ferromagnetic circuits.

### Energies, Fluids and Processes – Laboratory Fluid Compulsory E

Introduction to the fundamentals of energy technology, balancing of systems (mass, material and energy), state variables and fluid properties (gases and liquids), forms of energy and energy transformations, basics of heat transfer, energy conservation for fluid mechanics (Bernoulli equation) and thermodynamics (1st LT) for closed and open systems). Practical relevance through lab tests with heat exchangers, pumps, compressors.

### Energies, Fluids and Processes – Laboratory Thermo Compulsory E

Introduction to the basics of energy technology. Balancing of systems (mass, materials and energy) and state variables. Energy forms and energy conversions, basics of heat transfer, energy conservation (1st law for closed and open systems). Practical relevance through laboratory experiments with heat exchangers, fuel cells, compressors.

### Environmental Analysis & Ecology Compulsory E

Introduction to fundamental concepts of environmental engineering and ecology, including sustainability, ecosystems, biodiversity and climate system; environmental impact assessment; implications of CO<sub>2</sub> emissions and other pollutants on natural systems and human mankind; application of analytical and economic tools for evaluating environmental impacts and causes of environmental problems.

### Environmental Chemistry and Biology Compulsory E

Introduction into environmental chemistry and biology. Major characteristics of the five spheres of Earth's environment: geo-, hydro-, atmo-, bio- and anthrosphere supplemented by laboratory experiments. Categories of hazardous substances and their interaction with the spheres. Estimation of important aspects of selected pollutants. Inclusion of current environmental issues.

### Marketing Management and Accounting Compulsory G/E

Understanding the fundamentals of marketing, knowing and applying the methods of marketing research, conception, implementation and controlling, using financial information for decision making, applying basic financial and management accounting methods, basic understanding and ability to analyze financial reporting, applied in a management simulation.

**Mathematics 1A Compulsory E**

Elementary functions, Differential and Integral calculus of functions in one variable with applications.

**Mathematics 2A Compulsory E**

Complex numbers: normal and polar forms, Euler's formula, roots of complex numbers. First order differential equations: basic definitions, Euler's method, method of separation of variables and method of variation of the constant. Second order differential equation: Different types of differential equations in particular linear equations, homogeneous and inhomogeneous. Several applications to real word problems, in particular to harmonic oscillations.

**Mathematics 3A Compulsory E**

Functions of several variables, probability theory.

**Physics 1A Compulsory G/E**

Teaching of the fundamentals of mechanics. Dynamics of the mass point based on Newton's laws, work, energy, impulse and their conservation laws. Statics and motion of fluids: gravitational pressure, buoyancy, continuity equation, Bernoulli's equation, flow resistance.

**Physics 2A Compulsory E**

Introduction to thermodynamics. Treatment of the ideal gas equation. With the first law of TD, heat is introduced as another form of energy. Four basic changes of state in the ideal gas are treated in the p-v diagram, as well as the efficiency in cyclic processes. Harmonic oscillation is studied in the mass-spring system. The viscous damped oscillation is treated. Excited oscillation and the resonance curve are discussed. Harmonic waves, standing waves and sound waves conclude the mechanics.

**Materials Lab Compulsory E**

Introduction to Material Science and Engineering: Understand the structure and basic properties of materials, know how to derive properties by testing, understand test procedures and evaluations, able to assess aspects of material selection. Overview of the lifecycle of all relevant materials in Energy System engineering and their ecological footprint in production, use and end of life.

**Sustainable Energy Systems Compulsory E**

Addressing the question of "When do solutions deserve to be called «sustainable»?" Investigate methods and innovations that address conditions of new systems, including the provisioning of energy, its processing, distribution, application and conversion as well as environmental footprint and responsibility for everyone on our planet; focus on questions of economic feasibility.

**Systems Modelling Compulsory E**

Fundamentals of mathematical description of systems and introduction of modelling tools. Students learn how to describe mathematically a system (linear models), as well as how to implement and solve the system in e.g. MATLAB and Python. The basics from system thinking and engineering will be applied in practical examples.

**Technical Mechanics Compulsory G/E**

Introduction to design methods and materials selection in design process. Overview of machine elements and their applications. Introduction to engineering mechanics: plain statics and strength of materials.

**Thermodynamics and Fluid Dynamics Compulsory E**

In-depth analysis of conservation variables in fluid mechanics and thermodynamics, analysis of state changes and compressibility, meaning of friction (dissipation) and entropy (irreversibility), 2nd law of thermodynamics, analysis of the boundary layer and impact on practical applications. Extended introduction to heat exchange, dimensional analysis, similarities, key figures, clockwise and counterclockwise thermodynamic cycles.

## Core modules – Specialization in Energy Systems

### Electrical Power Grids **Compulsory/Elective E**

The following topics are covered: Transformation of primary into electrical energy. Fundamentals of the main grid components of a power system (generators, transformers, substation and transmission lines/cables). Grid analysis techniques such as load-flow and short-circuit calculation. Methods of power system control. Analysis of blackouts and concepts of protection systems.

### Energy Storage Systems **Compulsory/Elective E**

Principles of energy supply, with a focus on renewable energies. Importance, application and overview of energy storage. Planning and use of modern energy storage. Storage of thermal energy: Fundamentals of thermodynamics, exergy analysis and interpretation, modeling and application, thermal energy networks. Storage of electrical energy: fundamentals of electrical storage, analysis and interpretation. Modeling and applications and electrical networks. Combined use of thermal and electrical energy storage in networks and interplay of forms of energy (Power to Gas, Power to Heat, electro-thermal energy storage). Accompanying laboratory exercises on current topics in energy storage technology.

### Renewable Energies – Bioenergy

#### **Compulsory/Elective E**

The technologies for energy from biomass are presented with focus on combustion in residential and industrial applications for heat, combined heat and power (CHP), and dedicated power. Further, biofuels production by anaerobic digestion (biogas), fermentation (bioethanol) and synthesis are discussed. For relevant applications, investment costs are described and economic assessments of bioenergy production are discussed.

### Renewable Energies – Solar Energy **Compulsory/Elective E**

Imparting of physical fundamentals and technologies regarding the usage of solar energy. Along with solar heat in buildings also photovoltaics and concentrated solar thermal processes to generate electricity are discussed. Furthermore, planning fundamentals and commercial planning software as well as costs and profitability are part of the module.

### Energy Trading, Economics and Policies

#### **Compulsory/Elective E**

Examine structures and trends of trading renewable energies as opposed to trading “grey” energies as commodity, trading CO2 certificates and related products, innovations in this area, political guidelines, and their international ramifications.

## Core Modules – Specialization in Environmental Systems

### Environmental Technologies & Pollution Control *Compulsory/Elective E*

Introduction eco-design technologies avoiding end of life treatment e.g. design for reuse, refurbishment, or recyclability. Introduction of CO<sub>2</sub> abatement technologies comprising direct air capturing (DAC), carbon capture and storage (CCS) and CO<sub>2</sub> capturing and utilisation technologies, e.g. fixation of CO<sub>2</sub> by algae, biochar production for soil improvement, and technologies for synthetic fuel production.

### Environmental Law and Regulations *Compulsory/Elective E*

Analysis of the areas of environmental law that are most relevant for energy and environmental systems engineers, including, inter alia, air pollution, land use, water protection and climate law; examination of the basic structure of international, European and Swiss environmental law discussion of legal cases with peers using basic legal reasoning.

### Waste Management and Recycling *Compulsory/Elective E*

The Waste management and recycling course will give insight to the generation, collection, treatment, deposition and recycling of main waste categories. The existing management systems and applied technologies are analysed and evaluated. Crucial processes such as anaerobe digestion & composting, final disposal, thermal treatment, sorting & separation techniques, material recycling and energy recovery are covered. Waste categories which are not yet explicitly covered in this course, can be included e.g., through case studies or during excursions.

## Core Modules – Specialization in Environmental Systems

### Systems Engineering for Energy & Environmental Systems *Compulsory/Elective E*

Introduction to the design and management of complex systems over their life cycles. Appropriate delimitation of systems. Illustration of the complexity of energy and environmental systems. Possibilities to structure systems and to reduce complexity of systems.

### Water Management and Treatment *Compulsory/Elective E*

Basics of water supply, use and wastewater treatment; overview of water supply from groundwater, lakes and rivers, springs, boreholes, climate change pressure on water supply & new technologies; wastewater treatment standards (CH/Europe) and water saving technologies; individual case studies & excursions.

## Core modules – Elective

### Controlling *Elective E*

Managing a company in a business simulation using the Management Control and Accounting (from MM+RW) tools. These instruments comprise Management Information Systems, Business Cases, Capital Budgeting as well as tools for Management Control along the whole value chain.

### Strategic Management and Product Management *Elective E*

Fundamentals of strategic management, importance of corporate objectives, strategic analysis, strategic options, implementation, application in the context of a business simulation. Fundamentals of product and innovation management, incl. product lifecycle and portfolio analysis, requirements engineering and market introduction.

## Project modules

### Bachelor Thesis **Compulsory** *E*

Independent execution of very challenging task as an individual project within a company. Application and deepening of problem solving, project management and professional competencies learned during the course of study and under consideration of the systemic context. Creation of convincing scientific documentation and a presentation of the results.

### Context 1 **Compulsory** *G/E*

Step-by-step execution of a project by an interdisciplinary team of students, in product or process innovation coached by subject experts. Gain competences in the fields of project management, research, report writing and convincing presentations.

### Context 2 **Compulsory** *G/E*

Develop English for academic and professional purposes, i.e. English communication skills, furthering presentation techniques and clear concise writing of documents considering their target audience appropriately.

### Engineering Product Development Project 1 **Compulsory** *E*

Engineering project: experiencing the development of a product in an interdisciplinary team. Elaboration of market and product requirements; develop, evaluate and verify engineering solution concepts taking into account established ideas- and solution-finding methods. Set-up of suitable basic tests and prototypes for proof of concept.

### Engineering Product Development Project 2 **Compulsory** *E*

Exemplary engineering learning project with processing of an interdisciplinary project task in a team. As a continuation of PDP1, partial solutions are brought together, the solution is realised and implemented, and the overall concept is tested. In parallel, presentations, visualisations and technical documentation of the results are created.

### International Project **Elective** *E*

Hands-on introduction to Design Thinking and Business Models. Execution of a design thinking project within a team, solving a real life challenge provided by an industry partner. Application and deepening of problem solving, project management and professional competencies, including agile methods and work practices. Creation of convincing scientific documentation and presentation of the results.

### Industrial Project **Compulsory** *E*

Independent execution of an individual project within a company. Application and deepening of problem solving, project management and professional competencies under consideration of the systemic context. Creation of convincing scientific documentation and a presentation of the results.

### Practical Modules **Elective** *E*

Application and development of study-related subject-specific skills and knowledge as part of a project in a professional context; submission of project applications to the head of degree program; crediting of the acquired skills is made by semester.

### Practical Experience **Elective** *E*

Acquisition and expansion of practice-related technical, methodological and social skills and/or entrepreneurial experience in the environment based on the skills developed during the course; into competencies. Usually in cooperation with an external company or when setting up your own start-up.



## Related modules

### Basics of Electrical Drive Systems Elective E

Covering the functional principal, the equivalent circuit and the design fundamentals of the most common electrical machines and power electronic circuits like dc-converters, rectifiers, inverters and converters. Merging the components to efficient drive systems. Discussion of the advantage and disadvantages of the different systems.

### Building Technology Systems Elective E

The most important basics for electrotechnical but also HVAC-systems are considered in a differentiated way and the possibilities of systemic optimized concept solutions. Energy efficiency, low-tech approaches and the and synergetic interplay between energy supply, storage and distribution are conveyed on a conceptual level.

### B2B-Marketing Elective G/E

Basics of management activities that enable a firm to understand, create, and deliver value to other businesses, governments, and/or institutional customers. Inputs and case studies are used for understanding value, i.e. the examination of the three related business market processes; creating value through managing market offerings, new offering realization, and business channel management; and delivering value to customers by understanding the process of prospecting for new business relationships, assessing the mutual fit, making the initial sale, and fulfilling the initial order.

### Construction Physics for Building Technology Elective E

Introduction to building physics and building construction, outdoor climate, thermal comfort, steady and non-steady state thermal transmission, transparent elements, air exchange, transient behavior of buildings, energy and sustainability in the built environment, daylight.

### Design, build and commission Photovoltaic in Ethiopia (intensive week) Elective E

Many Health Centers in Ethiopia are far from grid connections. Childbirth mortality at night and cooling of vaccines is a big challenge. A 5 kW decentral Energy System, consisting of photovoltaic panels, batteries, and controls shall help. Participants team-up with local students from AMU (Arba Minch University) and learn together the sizing of the components at AST (Advanced Solar Training Center, carried out by professionals from Sahay Solar and HSLU). The learning and the equipment are then taken to a rural Health center, where the Energy system is constructed, commissioned and handed-over to the local operator.

### Design Fundamentals Elective G/E

This module gives an overview of the discipline and processes of industrial design and human centred design. Parts of the design process such as perception, ergonomics, creativity, needfinding and prototyping will be experienced through practical exercises. The ability to innovate is core of this module and will be practiced intensively.

### Digital Business Models Elective E

The module explains what business model innovation is and how this is embedded in strategic management. Students are introduced to the most important business model frameworks and provided with hands-on guidelines to select, develop, and apply them to digital technologies as an enabler for disruptive innovation. This will be applied to a real-life case studies.

### Digital Business Process Engineering Elective E

This module provides an introduction to the fundamentals, approaches and methods required for digital business process engineering on the basis of a cycle-based framework model (5 phases), which represents a typical management cycle. Different models, methods and techniques are applied, based on concrete practical examples. Transfer of knowledge is been facilitated and active work is necessary (group exercises, case studies).

**Energy Optimization with Pinch Analysis** Elective E

Refresher energy and process technology, fundamentals of Pinch Analysis and application of the engineering tool PinCH, representation of processes in composite curves, investment and operating costs, energy and cost targets, supertargeting, design of heat exchanger networks, optimization of utility systems, integration of heat pumps, combined heat and power systems, etc., introduction to batch and multiple base case process analysis, case studies from industry.

**Innovation Financing** Elective E

Introduction to corporate finance, approaches to innovation financing, determining risk and return of investments, understanding capital structure decisions, performing project and company valuation.

**International Marketing** Elective E

Importance of international marketing for companies being active in today's business environment, assessment of international environment, importance of cultural diversity, development of international marketing strategies and marketing instruments, management and organization of international marketing activities, application in case studies and in a business simulation in teams.

**Leadership (intensive week)** Elective E

Students shall understand the concept of leadership and its different aspects and success factors by looking at themselves, their teams and organizations. The training will be based on basic theoretical concepts but to make it more applicable in real life one of the key elements of the training is practicing with tools that leaders apply to be successful. One of the aims of the training is to prepare the students for their future roles as leaders: project leaders or product managers.

**Linear Algebra** Elective G/E

Basics of linear algebra including matrix algebra and its applications, in particular Euclidian vector space and linear maps, eigenvalues and eigenvectors; solution of mathematical problems with algebraic and numerical methods, their graphical representation, in particular, using numerical software as e.g. MATLAB or Python.

**New Business Development** Elective E

This module focuses on developing new business strategies and projects using strategic management, business model innovation, corporate finance, and project management. It uses case studies and covers intrapreneurship, ambidextrous organization design, venturing, mergers, acquisitions, joint ventures, negotiation tactics, legal aspects, and integration/change management.

**Operational Excellence** Elective E

Deepened analysis of the Supply Chain of industrial companies, in search of Excellence, based on the principles and tools of the Toyota Production System and its evolution into Lean Management. These concepts and tools will be explained and applied in several case studies and in a final production simulation game, so that participants will "touch with their hands" the significant difference between traditional and "lean" approaches in Operations.

**Sales Management** Elective E

Provides an understanding of sales organisations and teaches processes for managing and motivating sales staff as well as measuring and optimising success. You will learn how to develop appropriate sales strategies and select effective/efficient tools. You will learn to understand important features of sales psychology, apply essential sales practices, and negotiation and presentation techniques.

**Service Innovation** Elective E

Focus on creating, delivering, and capturing value from service innovation within complex product-service systems. Due to the entrepreneurial nature of the module, lean start-up and other business development approach to innovation will be used. The module is split into four episodes: i. understanding your capabilities; ii. understand your environment; iii. innovate and develop; iv. share and sell.

**Statistical Data Analysis** Elective E

Foundations of probability theory and statistics, comprehension and interpretation of summary statistics and distributions, analysis of data samples, dealing with estimation and test problems, setting up a suitable experimental design, analyzing and interpreting regression models.

**Applied Machine Learning and Predictive Modelling** Elective E

Regression analysis: multiple linear regression with parameter assessment, graphic validation of models, variable transformations, prediction and confidence intervals for target variables, statistic tests and confidence intervals for parameters, variable selection, Ridge and Lasso Regression. Classification: classification concepts, logistic regression, CART, random forests, support vector machines (SVM) and model evaluation through cross validation. Time series analysis: descriptive time series analysis, STL disassembly, autocorrelation, AR and ARIMA model with parameter assessment, GARCH, confidence and prediction bands, model selection.

**Supply Chain Management** Elective E

Introduction to the Supply Chain of industrial companies, through examples from various businesses, analysis and discussion of business cases, including the use of Supply Chain simulations. Starting with a high-level view of the Supply chain across several tiers, then analysing in detail the Logistic activities in a company. Moving to Sourcing strategies and tools for strategic and operational Purchasing, Ending with Production, Costing, Risk management and Sustainability.

**Usability** Elective E

The human being in direct interaction with systems, definitions of usability and user experience, human centred design process and its integration into a general project approach, GUI design, various interaction elements, usability and quality, usability and accessibility, usability and special technologies (e.g. AR/VR, hardware).

**Windpower and Ecotechnology**  
(intensive week) Elective E

Basics of wind energy engineering, starting with determination of wind power potentials, applied to different kinds of turbines and systems including selection of materials and components up-to the estimation of electrical power production. Based on actual installations, stakeholder analysis and environmental impact analyses are applied to assess the impact of emissions on humans and ecosystems.

**Energy Data Analytics & Forecasting**  
(intensive week) Elective E

In this intensive week, we consider how machine learning can be used to help solve the energy forecasting problem. The participants will apply those algorithms to specific use cases regarding photovoltaics, e-mobility, storage or self-consumption optimization in order to predict load and/or production. Real-world data will be used, and practical experience will be provided by the experienced lecturers that facilitate the course. Through your project you will have practical examples that can be taken forward in your academic or professional life.

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Further information  
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