

Energy and Environmental Systems Engineering

Curriculum
2024/2025

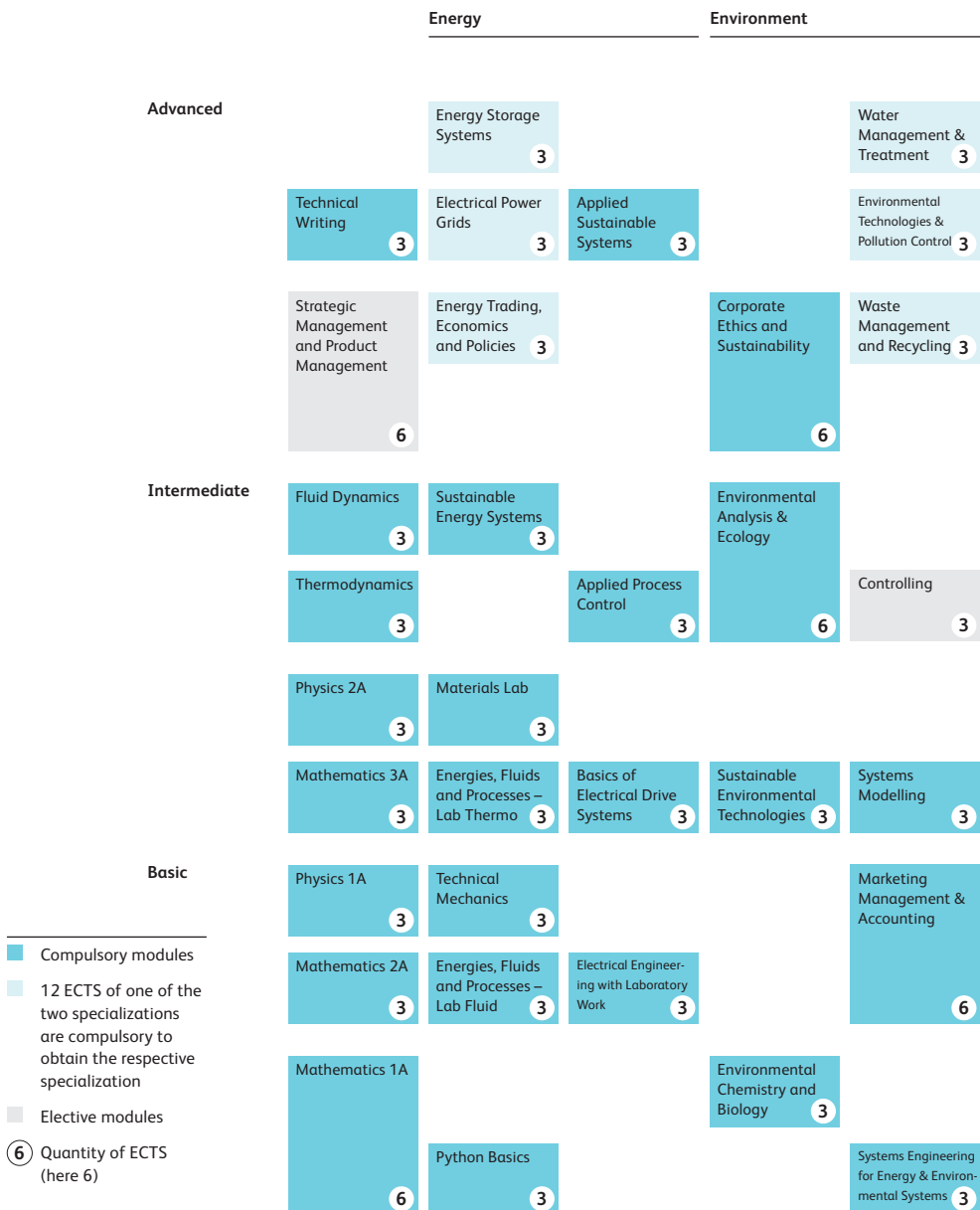
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Structure of the Bachelor program

Core modules

At least 90 ECTS credits are to be earned



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 Sustainable Business Development

3

Digital Business Process Engineering

3

Operational Excellence

3

Sales Management

3

Supply chain Management

3

Service Innovation

3

Energy Optimization with Pinch Analysis

3

Innovation Financing

3

Energy Data Analytics & Forecasting (intensive week)

3

Leadership (intensive week)

3

Applied Machine Learning and Predictive Modeling

3

Design, build and commission Photovoltaic in Ethiopia

3

Python Advanced

3

Statistical Data Analysis

3

Usability

3

International Marketing

3

B2B Marketing

3

Linear Algebra

3

Design Fundamentals

3

Windpower and Ecotechnology

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.

Applied Sustainable Systems Compulsory E

The goal of this module is to give students a solid knowledge of the most essential technologies and methodologies for the design and implementation of sustainable energy systems.

Basics of Electrical Drive Systems Compulsory 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.

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

Introduction to the basics of electrical engineering. Use of exercises and associated laboratory exercises to familiarize students with the basic building blocks and basic laws of electrical engineering.

Energies, Fluids and Processes – Laboratory Fluid Compulsory E

Introduction into basics of Energy Technology (Fluid Dynamics). System balancing (mass, energy and momentum). Different types of energy and energy conversion. Basics of fluid motion. Flow regimes and losses in fluid flows. Laboratory tests using various flow configurations (geometries), pumps and turbines.

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 analysis and ecology, including sustainability, ecosystems, biodiversity and climate system; environmental impact assessment; implications of CO2 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 to environmental chemistry and biology. Key characteristics of Earth's spheres: geo-, hydro-, atmo-, bio-, and anthrosphere, supplemented by lab experiments. Element cycles and hazardous substances interacting with organisms.

Fluid Dynamics Compulsory E

In-depth treatment of conservation theorem in fluid mechanics. Potential theory and application to frictionless flows. Importance of friction (dissipation), boundary layers and effects in practical applications. Resistance of flowing bodies. Dimensional analysis, similarities and key figures. Treatment of compressible flows (supersonic).

Marketing Management and**Accounting Compulsory G/E**

Fundamentals of marketing, knowledge and application of the methods of marketing research, conception, implementation and controlling, use of financial reporting and its analysis as well as cost accounting (cost accounting, contribution margin accounting and costing as instruments for decision-making, applied in a business game throughout the semester.

Materials Lab Compulsory E

Introduction to Material Science and Engineering: Structure and basic properties of materials, 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.

Mathematics 1A Compulsory E

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

Mathematics 2A Compulsory E

Complex numbers: normal and polar forms, Euler's formula. 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 world problems, in particular to harmonic oscillations.

Mathematics 3A Compulsory E

Functions of several variables, partial derivatives, total differential, gradient, linear and non-linear optimisation of functions of several variables, integrals in dimension 2 and 3, applications to science, technology and economics, in particular using numerical software such as Python.

Physics 1A Compulsory G/E

Teaching the basics of mechanics. Dynamics of the center of mass on the basis of Newton's laws, work, energy, momentum and their law's of conservation. Statics and motion of fluids: hydrostatic pressure, buoyancy, continuity equation, Bernoulli equation, flow resistance.

Physics 2A Compulsory E

The basics of thermodynamics, oscillations and waves are studied. Main topics are the ideal gas, the first and second law of thermodynamics, cyclic processes in the pV diagram, as well as the thermodynamic efficiency. Harmonic, damped and driven oscillations are investigated. The study of harmonic waves, especially sound waves complete the semester.

Python Basics Compulsory G/E

Introduction to Python programming with a focus on variables, operators, branching and loops using Jupyter notebooks. Learning how to use libraries such as numpy, pandas and matplotlib for mathematical calculations and data analysis. Covering data structures such as lists and arrays as well as basic concepts of file processing and error handling. Fundamentals of stochastics, including location and dispersion measures, regression, correlation and probability calculations.

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.

Sustainable Environmental**Technologies Compulsory E**

The Sustainable Environmental Systems module (UT) describes the specialisation "Environment" and lays the foundations for three subsequent environmental modules. Students are introduced to soil, water, and air compartments analogous to the technologies for waste treatment, wastewater purification and air pollution control. Students gain in-depth insights into selected environmental chemical and biological processes as well as the applicable regulatory and legal framework conditions.

G/E = Module offered in German and English

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.

Systems Modeling 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 E

This course enables students to calculate simple static problems within the field of mechanics to pre-evaluate the support reaction, forces, momentum, stress and strain acting inside a body to determine its strength and safety.

Technical Writing Compulsory/Elective E

The module TECW enables students to consolidate the skills they need when writing a scientific technical report on a project that are required at Advanced level in the Bachelor of Engineering degree program. Students write a scientific project report for their Industrial Project (PAIND). To this end, they prepare an Exposé to gain clarity about the initial situation and their research approach and to argue these coherently. In addition, they submit 2 more chapters of the final report (PAIND). Individual Coachings (1-1) support them to gain those skills.

Thermodynamics Compulsory E

In-depth treatment of the conservation laws in thermodynamics, treatment of state changes and their effects in practical applications, irreversibility and the second law of thermodynamics, extended introduction to heat transfer, 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 technics such as load-flow and short-circuit calculation. Methods of power system control. Analysis of blackouts and concepts of protection systems. Renewable generation and their integration in power grids. Smart grid technologies and modern power system management with flexibility.

Energy Storage Systems Compulsory/Elective E

Principles of energy supply, focussed on renewable energies. Importance, application, overview of planning and use of energy storage. Thermal energy: Fundamentals of thermodynamics, exergy analysis and interpretation, modeling and application, thermal energy networks. Electrical energy storage: fundamentals of electrical storage, analysis and interpretation. Modeling and applications and electrical networks. Combined use.

Energy Trading, Economics and Policies

Compulsory/Elective E

Understand the drivers of today's energy agenda. Learn the tools of energy trading as a commodity. 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. Discover the policy tools to incentivize and promote the proliferation of renewable energies.

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 CO₂ abatement technologies comprising direct air capturing (DAC), carbon capture and storage (CCS) and CO₂ capturing and utilisation technologies, e.g. fixation of CO₂ by algae, biochar production for soil improvement, and technologies for synthetic fuel production.

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.

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

Students apply accounting concepts and information to successfully manage their own company in competition with their fellow students.

Strategic Management and Product Management **Elective** E

Fundamentals of strategic management, strategic analysis, corporate objectives, 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 Module T1 **Compulsory** *G/E*

Developing an interdisciplinary project with students from different degree programs; teaching specialist knowledge and English for academic purposes for writing an academic paper and giving a scientific presentation; promoting project-oriented and systematic thinking as well as interdisciplinary cooperation.

Context Module 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, Business Models, Circular Economy and Cross Cultural Theory. Project based working, bilingual, junior coach experience.

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

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

Regressionsanalyse: Multiple lineare Regression mit Parameterschätzung, Graphische Validierung von Modellen, Variablentransformationen, Vorhersage- und Vertrauensintervalle für Zielvariablen, statistische Tests und Vertrauensintervalle für Parameter, Variablenselektion, Ridge-Regression, Lasso.

Klassifikation: Konzepte der Klassifikation, Logistische Regression, CART, Random Forests, Support Vector Machines (SVM) und Modellevaluierung durch Cross-Validierung.

Zeitreihenanalyse: Deskriptive Zeitreihenanalyse, STL Zerlegung, Autokorrelation, AR und ARIMA Modell mit Parameterschätzung, Zeitreihenprognose.

B2B-Marketing **Elective G**

Grundlagen, Bedeutung und Abgrenzung des Industriegütermarketings. Erlernen und Anwenden der relevanten Konzepte und Vermarktungsbesonderheiten im Bereich der Industriegüter. Erarbeitung, Diskussion und Anwendung der hierzu essentiellen Instrumente mit Fokussierung auf die drei zentralen Perspektiven zur Bestimmung eines komparativen Konkurrenzvorteils sowie der vier essentiellen Geschäftstypologien für das Produkt-, Projekt-, System- und Integrationsgeschäft.

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**

The module provides an understanding of the discipline and process of industrial design and human-centred design. Sub-areas of the design process such as perception, ergonomics, creativity, needs analysis, idea generation and prototyping are experienced in practical exercises. The ability to think innovatively is emphasised and intensively trained.

Digital Business Models **Elective E**

The Digital Business Model Innovation module explores innovative business models enabled by digital technology. Students learn key frameworks, evaluate approaches, and apply knowledge through case studies. They emerge prepared to lead digital transformation and gain competitive advantages in today's dynamic marketplace.

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 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.

Energy Optimization with Pinch Analysis Elective E

Fundamentals of Pinch Analysis and PinCH tool, processes representation in composite curves, investment and operating costs, energy and cost targets, supertargeting, heat exchanger networks design, utility systems optimization, heat pumps integration, combined heat and power systems, etc., introduction to batch and multiple base case process analysis, thermal energy storage integration analysis, case studies.

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 Sustainable Business Development Elective E

This module focuses on developing new business in the area of sustainability. Companies are analyzed using known frameworks and tools in the area of product- and strategic management, sustainability, circular economy, business model innovation, corporate finance, and project management. It uses case studies and covers sustainability, agile methods, intrapreneurship, ambidextrous organization design, corporate venturing, mergers, acquisitions and joint ventures, legal aspects, and integration/change management. Real cases and companies are analyzed and described. New ideas and concept for sustainable products and businesses are proposed. The New business development approach in the companies and results are summarized in case study in form of a book article. The (good) cases studies are published in a book.

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.

Python Advanced Elective E

Advanced aspects of object-orientated Python programming with practical tasks on a provided Raspberry Pi. Treatment of the Linux operating system and insights into the integration of Azure and SQL databases as well as the advantages of MQTT communication.

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

The service innovation module equips students with key concepts like value co-creation and service-dominant logic, enabling them to blend tangible and intangible. Through case studies and hands-on guidance, students learn to evaluate strategies and design innovative services, fostering a strategic mindset for leading innovation in various industries.

Statistical Data Analysis Elective G

Grundlagen der Bayesschen und frequentistischen Wahrscheinlichkeitsrechnung und Statistik, Verständnis von Kenngrößen und Verteilungen, Analyse von Stichproben, Auseinandersetzung mit Schätz- und Testproblemen, Aufsetzen eines geeigneten Versuchsplans, industrielle Prozessoptimierung.

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. Stakeholder analysis and environmental impact analyses are applied to assess the impact of emissions.

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Further information
about the Bachelor of Science
in Energy and Environmental
Systems Engineering