HOCHSCHULE ANSBACH

Modulhandbuch

Smart Energy Systems (SPO WS 21/22)

Fakultät Technik

Stand: 2023-02-08

Inhalt

1 Introduction to the course of studies

Smart Energy Systems			
Short form:	SES	**SPO no.:**	HSAN-20212
Program Director:	Prof. Dr.-Ing. Jungwirth, Johannes		
Study Counseling:	Prof. Dr.-Ing. Jungwirth, Johannes		
ECTS:	90 points		
Normal period:	3 semesters		
Prerequisite for participation:	Successfully completed university degree in a relevant degree programme or an equivalent domestic or foreign degree with an overall examination grade of at least 2.3, the scope of which usually comprises 210 ECTS credits, but at least 180 ECTS credits, is required. Knowledge of English language at level B2 and German language at level A2.		
Usability:	Master Smart Energy Systems		

Learning outcomes:

The general goal of the master's program Smart Energy Systems is to provide engineers and scientists with expert knowledge of energy systems and especially the interaction between the single components of the system as well as the optimization of the system.

The master's program prepares students for the future work as managers or experts in the field of smart energy systems or related industries. Based on their previous studies, the students develop skills in order to meet the requirements of the energy sector and other energy related industries.

The worldwide shift from fossil to renewable energy sources leads to a rising demand of experts in the field of smart energy systems. Graduates have comprehensive skills that directly address the demands of decarbonized, decentralized and digital energy systems. In addition to the energy technology and energy economy related skills, graduates also know who to deal with simulation systems, can understand and apply technologies in the field of artificial intelligence and have advanced programming skills for different target systems such as real-time devices. Besides that, graduates understand the use of IoT (Internet of Things) appliances and are able to transfer that knowledge to address energy related tasks. With their advanced skills in virtual power plants, blockchain and optimization in combination with their entrepreneurial training, graduates are prepared to develop new processes, products and business models in smart energy related industries as well as solve problems in the traditional energy industry.

The course takes into account theoretical and practical background in a balanced way, which is taught in an application-oriented manner. Graduates are enabled to work in international energy and energy related companies and institutions, small and medium-sized companies, public authorities and energy suppliers. Graduates are also prepared to start a career as entrepreneur and open up a new start-up company as founder or co-founder as well as support start-up companies as employees such as manager or expert.

Content:

In the first semester, the Energy Systems / Energy Economics module teaches elementary technical knowledge about the components and participants of the energy system. The simulation of decentralised energy systems is one of a total of five digital modules in the first semester, in which the interaction of the individual participants in the energy system with each other is dealt with. In IoT Technologies and Data Interfaces, students learn how digitally networked, intelligent systems are created through sensor technology and inter-

net connection. With the basics of programming in LabVIEW, an easy-to-learn graphical programming environment, and the basics of artificial intelligence, the focus is on computer-based problem solving and analysis. A compulsory elective module allows a look at other exciting topics in both the first and second semesters.

In the second semester, Virtual Power Plant is concerned with another essential component for the energy systems of the future, namely the connection of decentralised energy producers with systems for storing or otherwise using surplus energy in so-called power-to-X plants for a reliable supply. How such systems communicate safely with each other and make decisions autonomously - without human intervention - is the topic of the module AI Applications in Energy Systems / Blockchain. Entrepreneurial thinking and action sheds light on energy entrepreneurship - new business models through digitalisation. Selected guest lecturers from the business world present their personal success stories as entrepreneurs and encourage students to realise their own ideas, for example in start-ups. Optimisation / Operations Research picks up on the knowledge and tools from the first semester in order to be able to optimally align and operate even complex systems using simulation. "Hands on!" is the motto in the project work - networked energy landscape, where students plan, implement and present their own project - an ideal preparation for later professional life.

The third semester allows students to deepen their knowledge of selected topics in the master's thesis, which is planned in cooperation with various companies. The master's seminar on scientific work accompanies the master's thesis, opens up the exchange between students in the form of lectures and provides the tools for a solid scientific approach.

According to the study plan and module plan the standard period is 3 semesters and comprises 90 credit points.

Student with a degree of 180 credit points must complete additional bridging semester comprising 30 credit points within the first year of the study. These credits can be achieved through additional electives, internship reports or scientific reports about work experience of minimum 1 year in a relevant field.

The first and the second semester consist each of 5 mandatory modules (5 ECTS each) and one compulsory elective. The third semester contains the master’s thesis and the master’s seminar scientific work, that supports the scientific exchange and provides additional skills during the period of the master’s thesis.

Graduation / Academic degree:

Master of Engineering (M.Eng.)

2 Description of Modules

2.1 Allgemeine Pflichtfächer

Energy Systems & Energy Economy

Module abbreviation:	SES-EnergySystemsEnEconomy	**Reg.no.:**	1
Curriculum:	**Programme**	**Module type**	**Semester**
	Smart Energy Systems (SPO WS 21/22)	compulsory module	1

Responsible for module:	Rosenbauer, Georg
Lecturers:	Rosenbauer, Georg
Language of instruction:	English
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 45 h Self-study: 105 h Total: 150 h
Subjects of the module:	1: Energy Systems & Energy Economy (SES-EnergySystemsEnEconomy)
Lecture types:	Seminar-based teaching
Examinations:	1: written exam, 90 minutes (SES-EnergySystemsEnEconomy) Prerequisite for granting credit points is that the respective module examination is passed in accordance with the SPO and study plan.

Prerequisites according examination regulation:

According to study and examination regulations and study plan

Recommended prerequisites:

None

Objectives:

Technical and methodological competence:

Students gain an overview on electricity market designs and understand the methods of grid operation in deregulated markets.

Professional action competence:

Students can develop investment and operating decisions based on the appropriate economic data.

Social skills:

In a comprehensive business simulation game students will cooperate to develop business strategies and coordinate their subtasks.

Content:

Energy balances: physical energy balance, energy process chains and Sankey diagrams, primary energetic evaluation in statistics.

Basic terms of plant operation: equivalent operating hours, load duration curves.

Investment calculation: financial mathematics, static and dynamic methods, financial planning models, balance sheet.

Economical aspects of power plant operation: fixed vs. variable costs, marginal costs, contribution margin, impact on operating decisions and investment decisions.

Aspects of grid operation: simultaneity, economies of scale, portfolio benefits, natural monopolies, vertically integrated utilities.

Distributed generation: economic drivers, distribution grid issues, concepts of grid friendly operation. Deregulated electricity markets: unbundling, TPA, forward vs. spot markets, pay as bid vs. market clearing price, merit order. Grid operation in deregulated markets: portfolio management, load balancing, congestion management. Smart energy: flexibility demand, sector coupling, sources of flexibility, optimization strategies.
Literature:
• KONSTANTIN, Panos and Margarete KONSTANTIN, 2018. *Power and Energy Systems Engineering Economics: Best Practice Manual*. Cham: Springer. ISBN 978-3-319-72383-9 • STERNER, Michael and Ingo STADLER, 2019. *Handbook of energy storage: demand, technologies, integration*. Translation of 2. edition. Berlin: Springer. ISBN 978-3-662-55503-3

Simulation of Energy Systems

Module abbreviation:	SES-SimulationEnergySystems	**Reg.no.:**	2
Curriculum:	**Programme**	**Module type**	**Semester**
	Smart Energy Systems (SPO WS 21/22)	compulsory module	1

Responsible for module:	Jungwirth, Johannes
Lecturers:	Matschi, Christoph
Language of instruction:	English
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 45 h Self-study: 105 h Total: 150 h
Subjects of the module:	2: Simulation of Energy Systems (SES-SimulationEnergySystems)
Lecture types:	Simulation of energy systems: seminar-based teaching
Examinations:	2: projekt work, 10 pages (SES-SimulationEnergySystems) Prerequisite for granting credit points is that the respective module examination is passed in accordance with the SPO and study plan.

Prerequisites according examination regulation:

According to study and examination regulations and study plan

Recommended prerequisites:

none

Objectives:

Technical and methodological competence:

By the end of this course, students

- know the basic components of a centralized and decentralized energy systems
- understand how the basic components of a centralized and distributed energy systems interact
- are able to simulate simple centralized and decentralized energy systems

Professional action competence:

By the end of this course, students

- are able to build simulation for simple energy systems
- are able to check simulation results of simple energy systems for plausibility
- are able to optimize simple energy systems to a target value
- able to transform real energy systems into simulation models

Social skills:

By the end of this course, students

- are able to gain knowledge and sum up the key facts independently
- can present technical knowledge in a professional way

Content:
• Operation of industry standard simulation software • Programming of closed-loop and open-loop control systems • plausibility checks • Modeling
Literature:
• will be specified during lecture

IoT Technologies and Data Interfaces

Module abbreviation:	SES-TechnologiesDataInterfaces	**Reg.no.:**	3
Curriculum:	**Programme**	**Module type**	**Semester**
	Smart Energy Systems (SPO WS 21/22)	compulsory module	1

Responsible for module:	Vaidya, Haresh
Lecturers:	Vaidya, Haresh
Language of instruction:	English
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 45 h Self-study: 105 h Total: 150 h
Subjects of the module:	3: IoT Technologies and Data Interfaces (SES-TechnologiesDataInterfaces)
Lecture types:	IoT Technologies and Data Interfaces (SES-IoTTechnologiesDataInterfaces)
Examinations:	3: written exam, 60 minutes (SES-TechnologiesDataInterfaces) Prerequisite for the granting of credit points is the passing of the respective module examination in accordance with the SPO resp. study plan.

Prerequisites according examination regulation:

According to study and examination regulations and study plan

Recommended prerequisites:

none

Objectives:

Technical and methodological competence:
By the end of this course, students

- know the functionality of a variety of IoT (Internet of Things) devices
- understand the communication technologies and data interfaces that are used to transfer data between different devices, servers and other infrastructure

Professional action competence:
By the end of this course, students

- are able to apply smart technologies to energy production, consumption and storage technologies and value added services
- can evaluate how IoT-Technologies can lead to new or improved processes or even new products and services in the energy sector

Social skills:
By the end of this course, students

- are able to gain knowledge and sum up the key facts independently
- can present technical knowledge in a professional and entertaining way

Content:
• Internet of Things devices and their Hardware and Software • Data Interfaces and Data communication • IoT-server and infrastructure
Literature:
• will be specified during lecture

LabVIEW Programming

Module abbreviation:	SES-LabVIEW Programming	**Reg.no.:**	4
Curriculum:	**Programme**	**Module type**	**Semester**
	Smart Energy Systems (SPO WS 21/22)	compulsory module	1

Responsible for module:	Jungwirth, Johannes
Lecturers:	Jungwirth, Johannes
Language of instruction:	English
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 45 h Self-study: 105 h Total: 150 h
Subjects of the module:	4: LabVIEW Programming (SES-LabVIEW Programming)
Lecture types:	SES-LabVIEW Programming: seminar-based teaching
Examinations:	4: written exam, 60 minutes (SES-LabVIEW Programming) Prerequisite for the granting of credit points is the passing of the respective module examination in accordance with the SPO resp. study plan.

Prerequisites according examination regulation:

According to study and examination regulations and study plan

Recommended prerequisites:

Basic programming skills in any programming language

Objectives:

Technical and methodological competence:

By the end of this course, students

- Know basic techniques of software development and programming
- Understand the particularities of LabVIEW programming

Professional action competence:

By the end of this course, students

- Are able to apply their programming skills to develop software applications with LabVIEW
- Can analyze, test and debug LabVIEW VIs (virtual instruments)

Within the modules students have the possibility to get the industry certificate “Certified LabVIEW Associate Developer – CLAD”

Social skills:

By the end of this course, students

- Can independently work on programming tasks

Content:
• LabVIEW Programming environment • Creating applications • Debugging and Troubleshooting • Using Loops • Using Decision-making-structures • Modularity • Accessing files in LabVIEW • Sequential and state-based designs • Variables and the communication of data between parallel loops • Design patterns • Controlling the user interface • File IO techniques • Creating and distributing applications
Literature:
• LabVIEW Core 1 participant guide • LabVIEW Core 2 participant guide • Nation Instruments online Knowledge Database: www.ni.com

Artificial Intelligence Basics

Module abbreviation:	SES-ArtificialIntelligenceBasics	**Reg.no.:**	5
Curriculum:	**Programme**	**Module type**	**Semester**
	Smart Energy Systems (SPO WS 21/22)	compulsory module	1

Responsible for module:	Jungwirth, Johannes
Lecturers:	Taverne, Jean-Michel
Language of instruction:	English
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 45 h Self-study: 105 h Total: 150 h
Subjects of the module:	5: Artificial Intelligence Basics (SES-ArtificialIntelligenceBasics)
Lecture types:	Seminar-based teaching
Examinations:	5: project work, 10 pages (SES-ArtificialIntelligenceBasics) Prerequisite for granting credit points is that the respective module examination is passed in accordance with the SPO and study plan.

Prerequisites according examination regulation:

According to study and examination regulations and study plan

Recommended prerequisites:

None

Objectives:

Technical and methodological competence:

- Fields of application and example applications of AI
- Data science - fundamentals and methods for discovering patterns in large data
- Challenges and limits of AI

Professional action competence:

- Analysing, planning and selecting AI and data science methods according to requirements
- Effective and efficient implementation of the methods (configuration of methods, etc.) with appropriate tools
- Evaluation of the success of the applications and identification of optimization measures

Social skills:

- Communication and presentation skills, regarding the new, complex, and dynamic AI terminology, to be able to communicate with both users (business understanding) and technical AI experts (group work, case studies).
- Ability to work in a team in interdisciplinary project teams

Content:

In the module "Basic AI" the following contents are taught:

- Overview of application areas of AI (industries, subject areas, business areas).
- Introduction to data science tools and analysis languages and frameworks (Knime, Jupyter, Python & Pandas, Scikit-Learn, Tensorflow).
- Areas of Artificial Intelligence in detail, especially Machine Learning, Deep Learning
- Data Science I - meaning and basics
- Data Science II - approach, methods and tools (e.g. CRISP-DM (Cross Industry Standard Process for Data Mining): Business Understanding, Data Understanding, Data Preparation Modeling, Evaluation, Deployment)
- Data Science III - A machine learning project from A-Z
- Data Science IV - Methods of Supervised Learning - explained using practical examples
- Data Science V - Methods of Unsupervised Learning - Explained with practical examples like Anomaly Detection of Machine Learning
- Data Science V – Simple Introduction Deep Learning
- Challenges in the implementation of AI projects

In addition to teaching the content through seminar-style classes and practical examples using Python, we work together in a Scrum like Learning-Approach (Agile study).

Literature:

- GÉRON, Aurélien, September 2019. *Hands-on machine learning with Scikit-Learn, Keras, and TensorFlow: concepts, tools, and techniques to build intelligent systems*. S. edition. Beijing ; Boston ; Farnham ; Sebastopol ; Tokyo: O'Reilly. ISBN 978-1-492-03264-9, 1-492-03264-6
- MCKINNEY, Wes, October 2017. *Python for data analysis: data wrangling with Pandas, NumPy, and IPython*. S. edition. Beijing ; Boston ; Farnham ; Sebastopol ; Tokyo: O'Reilly. ISBN 978-1-491-95766-0
- Selected scientific papers on the topics of the course (the papers for the course will be provided in Moodle)

Virtual Power Plants

Module abbreviation:	SES-VirtualPowerPlants	**Reg.no.:**	7
Curriculum:	**Programme**	**Module type**	**Semester**
	Smart Energy Systems (SPO WS 21/22)	compulsory module	2

Responsible for module:	Jungwirth, Johannes
Lecturers:	Jungwirth, Johannes
Language of instruction:	English
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 45 h Self-study: 105 h Total: 150 h
Subjects of the module:	7: Virtual Power Plants (SES-VirtualPowerPlants)
Lecture types:	SES-VirtualPowerPlants: seminar-based teaching
Examinations:	7: written exam, 60 minutes (SES-VirtualPowerPlants) Prerequisite for the granting of credit points is the passing of the respective module examination in accordance with the SPO resp. study plan.

Prerequisites according examination regulation:

According to study and examination regulations and study plan

Recommended prerequisites:

Basic knowledge about energy economy and energy technologies

Objectives:

Technical and methodological competence:

By the end of this course, students

- Know the structure of virtual power plants
- Understand which technologies are used in virtual power plants

Professional action competence:

By the end of this course, students

- Are able to apply the idea of virtual power plants to different scenarios of energy producers and consumers
- Can analyze different technical and economical use-cases for virtual power plants

Content:

- Motivation: Why do we need virtual power plants?
- Introduction to virtual power plants, their basic structure and use-cases
- Energy production, energy consumption and energy storage technologies
- Sector coupling and Power-to-X technologies

- Demand-Side-Management
- Marketing opportunities for virtual power plants
- Power plant operations strategies
- Connectivity and Remote Control
- Practical examples of virtual power plants

Literature:

- DOLESKI, Oliver D., KAISER, Thomas, METZGER, Michael, NIESSEN, Stefan, THIEM, Sebastian, 2022. *Digital Decarbonization: Achieving climate targets with a technology-neutral approach* [online]. Wiesbaden: Springer Fachmedien Wiesbaden PDF e-Book. ISBN 978-3-658-33330-0. Available via: https://doi.org/10.1007/978-3-658-33330-0.

Energy Entrepreneurship			
Module abbreviation:	SES-EnergyEntrepreneurship	**Reg.no.:**	8
Curriculum:	**Programme**	**Module type**	**Semester**
	Smart Energy Systems (SPO WS 21/22)	compulsory module	2

Responsible for module:	Jungwirth, Johannes
Lecturers:	Hähnlein, Johannes
Language of instruction:	English
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 45 h Self-study: 105 h Total: 150 h
Subjects of the module:	8: Energy Entrepreneurship (SES-EnergyEntrepreneurship)
Lecture types:	Seminar-based and workshop-based teaching
Examinations:	8: presentation, 15 minutes (SES-EnergyEntrepreneurship) Pitch presentation with the respective team Prerequisite for granting credit points is that the respective module examination is passed in accordance with the SPO and study plan.

Prerequisites according examination regulation:

According to study and examination regulations and study plan

Recommended prerequisites:

None

Objectives:

By participating in the module energy entrepreneurship, the students gain specific and practice-oriented specialist knowledge as well as modern methods for developing and founding their own business. This includes the core areas of trend identification, idea generation, business design and go-to-market, specifically in the energy industry.

The module is designed as a practice-oriented workshop format in which the participants can apply the methods and specialist knowledge they have learned directly to their own project in a team and gradually develop their own founding idea and a corresponding business concept.

The aim of the course is that the participants, working in founding teams of 3-5 team members each, develop their own business concept and present it to an expert jury as part of a final pitch.

The module is characterized in particular by the following aspects:

- Practical relevance: The module deliberately does not work with fictitious case studies, but is intended to get the participants to develop their own product and business ideas in teams, which they can ideally pursue, develop and even put into practice beyond the event.
- Competence expansion: As participants in the module, students not only have the opportunity to apply the technical skills they have learned so far in a practical manner, but also to acquire skills that go beyond the technical and methodological competence, including product and business design as well as marketing and sales aspects.

- Innovation power: Exciting and creative methods combined with a structured setup of the module will promote the innovation power of the participating students and create a business concept based on their own marketable ideas as a relevant and realistic career option.
- Team competence: The participating students have to organize themselves independently in project teams and take on different roles, e.g. as team leader, technician, innovator or designer.
- Additional added value: The course can not only be included as a study module of the participating students, but can also include additional added value, such as
  - o Participation in the live pitch in front of a top-class jury,
  - o the opportunity to participate at the "Campus der Löwen" live-pitch event
  - o a spot for the winning team in the existence program; and
  - o the chance of further support through public funded programmes in case of a promising concept.

Acquired professional action competence:

- In the course, the students go through a realistic process of business design using state-of-the-art methods and skills;
- This initially includes the basic composition of a team;
- In the further course, the identification and systematization of methods and tools in the field of trend and innovation management, ideation, prototyping as well as market research takes place;
- The students also learn methods for generating product or service ideas, identifying fields of application, validation and business modelling;
- The students also learn and deepen key skills in the area of project management, problem-solving methods, business sub-disciplines, teamwork and communication skills as well as presentation techniques;
- By attending the event, the students can also assess an innovation process and go through it them-selves in corresponding project teams.

Acquired social skills:

- Creation, structuring and work coordination of business teams;
- Team-oriented work and content-related coordination of work;
- Focused and goal-oriented work under time pressure and focusing on the essential elements of product development;
- Demonstration and application of presentation skills through interim presentations and live pitches.

Content:

- Teambuilding
- Trend management
- Ideation
- Business Design
- Research & Development
- Validation
- Prototyping

- Startup Finance
- Marketing & Communications
- Pitching

Literature:

- OSTERWALDER, Alexander and others, 2020. *The invincible company: dieses Buch ist Ihr Guide zu den besten Geschäftsmodellen der Welt. Nutzen Sie es, um Ihr Ideen-Portfolio aufzufrischen und sich neu zu erfinden. So schaffen Sie eine Kultur der Innovation und Transformation, die Ihr Unternehmen unbesiegbar macht : strategyzer.com/invincible*. Frankfurt: Campus. ISBN 978-3-593-44477-2
- CHRISTENSEN, Clayton M., 2016. *The innovator's dilemma: when new technologies cause great firms to fail*. Boston, Massachusetts: Harvard Business Review Press. ISBN 978-1-4221-9602-1, 978-1-63369-178-0
- OSTERWALDER, Alexander and others, 2014. *Value proposition design: how to create products and services customers want*. Hoboken: John Wiley & Sons. ISBN 978-1-118-96806-2, 1-118-96806-9

Optimization of Energy Systems

Module abbreviation:	SES-OptimizationEnergySystems	**Reg.no.:**	9
Curriculum:	**Programme**	**Module type**	**Semester**
	Smart Energy Systems (SPO WS 21/22)	compulsory module	2

Responsible for module:	Moog, Mathias
Lecturers:	Moog, Mathias
Language of instruction:	English
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 45 h Self-study: 105 h Total: 150 h
Subjects of the module:	9: Optimization of Energy Systems (SES-OptimizationEnergySystems)
Lecture types:	Seminar-based teaching
Examinations:	9: written exam, 60 minutes (SES-OptimizationEnergySystems) Prerequisite for granting credit points is that the respective module examination is passed in accordance with the SPO and study plan.

Prerequisites according examination regulation:

According to study and examination regulations and study plan.

Recommended prerequisites:

Energy Systems and Energy Economy, Simulation of Energy Systems

Objectives:

Technical and methodological competence:

The students know different optimization methods with their advantages and disadvantages. They are familiar with the application of optimization methods in energy technology.

Professional action competence:

The students can convert energy technology issues into mathematical models and carry out optimizations.

Social skills:

During the practical training, students learn to work in groups on energy-related optimization issues.

Content:

The module consists of lectures including practical training. The following topics will be covered:

- Mathematical modelling
- Optimization procedures
- Use of optimization methods with computer support
- Apply optimization methods to energy-related issues

In the practical training, the optimization is mainly tested with Excel.

Literature:

- GERSHENFELD, Neil A., 2003. *The nature of mathematical modeling*. R. edition. Cambridge [u.a.]: Cambridge Univ. Press. ISBN 0-521-57095-6
- GIORGI, Giorgio, Angelo GUERRAGGIO and Jörg THIERFELDER, 2004. *Mathematics of optimization: smooth and nonsmooth case*. 1. edition. Amsterdam [u.a.]: Elsevier. ISBN 0-444-50550-4
- RAVINDRAN, A., Gintaras V. REKLAITIS and K. M. RAGSDELL, 2006. *Engineering optimization: methods and applications*. 2. edition. Hoboken, N.J.: Wiley. ISBN 978-0-471-55814-9, 0-471-55814-1
- GUERRERO, Hector, 2010. *Excel data analysis: modeling and simulation*. Berlin [u.a.]: Springer. ISBN 978-3-642-10834-1, 978-3-642-10835-8

Project Course - Smart Energy Systems

Module abbreviation:	SES-ProjectCourse	**Reg.no.:**	10
Curriculum:	**Programme**	**Module type**	**Semester**
	Smart Energy Systems (SPO WS 21/22)	compulsory module	2

Responsible for module:	Jungwirth, Johannes
Lecturers:	Jungwirth, Johannes
Language of instruction:	English
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 45 h Self-study: 105 h Total: 150 h
Subjects of the module:	10: Project Course - Smart Energy Systems (SES-ProjectCourse)
Lecture types:	SES-Projekt Course: practical training
Examinations:	10: presentation, 15 minutes (SES-ProjectCourse) Prerequisite for the granting of credit points is the passing of the respective module examination in accordance with the SPO resp. study plan.

Prerequisites according examination regulation:

According to study and examination regulations and study plan

Recommended prerequisites:

Basic LabVIEW Programming Skills

Objectives:

Technical and methodological competence:
By the end of this course, students

- know how to program and use real-time devices as NI myRIO
- understand how to develop distributed applications and remote controllable software on computers and real-time devices

Professional action competence:
By the end of this course, students

- are able apply real-time hardware and their self developed software to energy related applications
- can evaluate possible use-cases for real-time hardware to create new processes, functions or even products in the energy sector

Social skills:
By the end of this course, students

- know how to work together and organize in a team to reach a common goal in case of software development

• understand how to define processes and interfaces to put together single elements and sub-tasks to a project
Content:
• introduction to real-time hardware – NI myRIO • developing stand alone applications for NI myRIO • using remote frontpanels • using and developing web services • structured application development • final projects: using NI myRIO in smart energy systems
Literature:
• LabVIEW Core 3 participant guide • Additional online sources are published during the lecture

AI Applications in Energy Systems

Module abbreviation:	SES-AIApplicationsEnergySystems	**Reg.no.:**	11
Curriculum:	**Programme**	**Module type**	**Semester**
	Smart Energy Systems (SPO WS 21/22)	compulsory module	2

Responsible for module:	Schacht, Sigurd
Lecturers:	Lorenz, Maximilian
Language of instruction:	English
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 45 h Self-study: 105 h Total: 150 h
Subjects of the module:	11: AI Applications in Energy Systems (SES-AIApplicationsEnergySystems)
Lecture types:	Seminar-based teaching
Examinations:	11: projekt work, 10 pages (SES-AIApplicationsEnergySystems) Prerequisite for granting credit points is that the respective module examination is passed in accordance with the SPO and study plan.

Prerequisites according examination regulation:

According to study and examination regulations and study plan

Recommended prerequisites:

None

Objectives:

Technical and methodological competence:

- Example Applications and Implementations in the Field of Energy Systems
- Technical Understanding of Deep Neural Networks and Distributed Ledger Technology
- Methods to implement and test own AI Applications
- Challenges and limits of ANN and DTL

Professional action competence:

- Analysis, planning and selection of AI and Data Science methods according to requirements.
- Effective and efficient implementation of the methods (configuration of methods, etc.) with appropriate tools
- Evaluation of the success of the applications and identification of optimization measures

Social skills:

- Communication and presentation skills, regarding the new, complex and dynamic AI terminology and DTL Communication, to be able to implement own ideas as a prototype
- Ability to work in a team in interdisciplinary project teams

Content:

The subject consists of two main topics: AI, especially Deep Learning, as well as Distributed Ledger Technology.

In the first part of the course, deep neural networks are taught in the form of an in-depth study of the subject Basic AI.

- What is a neural network
- How does it work
- How do neural networks learn
- Which components are necessary? (network definition, backpropagation, optimizer)

Subsequently, different network typologies are explained in depth and internalized by means of common implementations from the field of Smart Energy Systems.

- Different network architectures of artificial neural networks
- Recurrent neural networks
- LSTMs
- Convolutional neural networks
- Transformers

In the second part of the course, the Distributed Ledger Technology will be discussed:

- What is meant by blockchain and distributed ledger technology.
- What is the consensus mechanism
- Application purposes of the DLT
- What are the advantages and disadvantages
- Application potentials in the field of smart energy systems

Literature:

- GALEONE, Paolo, 2019. *Hands-on neural networks with TensorFlow 2.0: understand TensorFlow, from static graph to eager execution, and design neural networks*. first published: September 2019. edition. Birmingham: Packt Publishing Ltd.. ISBN 978-1-78961-555-5, 1-78961-555-0
- BUDUMA, Nikhil and Nicholas LOCASCIO, June 2017. *Fundamentals of deep learning: designing next-generation machine intelligence algorithms*. F. edition. Beijing ; Boston ; Farnham ; Sebastopol ; Tokyo: O'Reilly. ISBN 978-1-491-92561-4, 1-491-92561-2
- SCHACHT, Sigurd and Carsten LANQUILLON, 2019. *Blockchain und maschinelles Lernen: wie das maschinelle Lernen und die Distributed-Ledger-Technologie voneinander profitieren*. Berlin: Springer Vieweg. ISBN 978-3-662-60407-6
- Selected scientific papers on the topics of the course (the papers for the course will be provided in Moodle)

Master's seminar Scientific Work

Module abbreviation:	SES-MastersSeminar ScientificWork	**Reg.no.:**	13
Curriculum:	**Programme**	**Module type**	**Semester**
	Smart Energy Systems (SPO WS 21/22)	compulsory module	3

Responsible for module:	Vaidya, Haresh
Lecturers:	Vaidya, Haresh
Language of instruction:	English
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 45 h Self-study: 105 h Total: 150 h
Subjects of the module:	13: Master's seminar Scientific Work (SES-MastersSeminar ScientificWork)
Lecture types:	SES-MastersSemScientWork: seminar-based teaching
Examinations:	13: participation and presentation (SES-MastersSeminar ScientificWork) Prerequisite for the granting of credit points is the passing of the respective module examination in accordance with the SPO resp. study plan.

Prerequisites according examination regulation:

According to study and examination regulations and study plan

Recommended prerequisites:

none

Objectives:

Technical and methodological competence:
By the end of this course, students

- Know the principles of scientific work and related skills
- understand how to structure and manage a project in the field of smart energy systems

Professional action competence:
By the end of this course, students

- are able apply basic techniques of project management to a energy related problem
- can analyze the state of the art of a specific topic in the field of smart energy systems and develop a solution for a specific problem

Social skills:
By the end of this course, students

- are able to find solutions for application- or research orientated tasks using appropriate resources and applying previously gained knowledge
- are able to summarize the most important content of a project and present the results to a professional audience

Content:
• scientific work • presentation skills
Literature:
• Will be specified at the beginning

Master's Thesis

Module abbreviation:	SES-MastersThesis	**Reg.no.:**	14
Curriculum:	**Programme**	**Module type**	**Semester**
	Smart Energy Systems (SPO WS 21/22)	compulsory module	3

Responsible for module:	
Lecturers:	
Language of instruction:	English
Credit points / SWS:	25 ECTS / 0 SWS
Workload:	Contact hours: 0 h Self-study: 750 h Total: 750 h
Subjects of the module:	14: Master's Thesis (SES-MastersThesis)
Lecture types:	SES-MastersThesis: master's thesis
Examinations:	14: master's thesis (SES-MastersThesis) prerequisite for the granting of credit points is the passing of the respective module examination in accordance with the SPO resp. study plan

Prerequisites according examination regulation:

According to study and examination regulations and study plan

Recommended prerequisites:

NONE

Objectives:

Technical and methodological competence:

By the end of this course, students

- Know the principles of scientific work and related skills
- Have advanced knowledge in a specific topic of smart energy systems

Professional action competence:

By the end of this course, students

- understand how to structure and manage a project in the field of smart energy systems
- get in touch with a problem in the field of smart energy systems and developing a solution

Social skills:

By the end of this course, students

- know how to structure a project and independently work on it, using additional sources and getting support from external persons and supervisors
- are able to summarize the most important content of a project and present the results to a professional audience

Content:
A supervising professor will provide a topic and accompany and support the work on the thesis. The workload should include following steps: • Analysis and structuring of the problem • Embedding of the problem into scientific context in the field of smart energy systems • Formulation and implementation of a solution • Design, execution and evaluation of suitable experiments/field tests/simulations • Documentation, discussion and presentation of the results
Literature:
• Will be specified at the beginning

2.2 Wahlpflichtmodule I

Drone basics

Module abbreviation:	SES-DroneBasics	**Reg.no.:**	6
Curriculum:	**Programme**	**Module type**	**Semester**
	Smart Energy Systems (SPO WS 21/22)		1

Responsible for module:	Jungwirth, Johannes	
Lecturers:	Abel, Oliver	
Language of instruction:	English	
Credit points / SWS:	5 ECTS / 4 SWS	
Workload:	Contact hours: Self-study: Total:	45 h 105 h 150 h
Subjects of the module:	6: Drone basics (SES-DroneBasics)	
Lecture types:	Seminar-based teaching	
Examinations:	6: written exam, 60 minutes (SES-DroneBasics) Prerequisite for granting credit points is that the respective module examination is passed in accordance with the SPO and study plan.	

Prerequisites according examination regulation:

According to study and examination regulations and study plan

Recommended prerequisites:

None

Objectives:

Participants will learn all the essential aspects to independently operate UAVs (Unmanned Aircraft Vehicles). One focus of the course is on the knowledge required for the official certificates of the Luftfahrtbun-desamt (A1/A3 for recreational pilots, A2 for more demanding applications and professional pilots). The course also gives an overview of the possible applications of drones in photography, video, thermography, and photo-grammetry.

Technical and methodological competence:

- Secure knowledge of the technical, legal, and organizational framework for UAV piloting.
- Knowledge of the possible applications of unmanned aerial vehicles in photography, videography, photo-grammetry, and engineering, e.g., for aerial inspection or measurement tasks.

Professional action competence:

- Ability to plan, prepare, execute, and follow up on drone operations for aerial photography (pho-to, video) and technical applications.

Social skills:

- Ability to work in a team to jointly develop and present exercises and project tasks in small groups.

Content:
• Clarification of terms UAV, drone, multicopter, etc. • Categories of drones and requirements for their operators • Basics of aviation law (EU and FRG), permit obligations, operating bans, special permits, technical-physical basics of flying UAVs • Technical structure of a drone, hardware, and software • Flight practice: Preparations for an ascent, basic flight manoeuvres, risks and their limitation, flight preparation and post-processing • Safety and technical-operational risk mitigation • Recording techniques and further processing of photo/video/data material. • Meteorology. Basic concepts and relevant constellations.
Literature:
• Current literature will be announced at the beginning of the course.

Energy System Technology

Module abbreviation:	SES-EnergySystemTechnology	**Reg.no.:**	6
Curriculum:	**Programme**	**Module type**	**Semester**
	Smart Energy Systems (SPO WS 21/22)		1

Responsible for module:	Buchele, Alexander
Lecturers:	Buchele, Alexander
Language of instruction:	English
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 45 h Self-study: 105 h Total: 150 h
Subjects of the module:	6: Energy System Technology (SES-EnergySystemTechnology)
Lecture types:	seminar-based teaching
Examinations:	6: written exam, 60 minutes (SES-EnergySystemTechnology) Prerequisite for granting credit points is that the respective module examination is passed in accordance with the SPO and study plan.

Prerequisites according examination regulation:

According to study and examination regulations and study plan

Recommended prerequisites:

none

Objectives:

Technical/methodical competence:
The students have an overview of the technical properties of renewable energy systems. You know the physico-chemical modeling principles for energy conversion and storage. They understand the application potential of the energy sources sun, wind, hydropower, biomass and geothermal energy, as well as hydrogen and thermal storage systems.
Action competence:
The students can calculate the technical application potential of different renewable energy systems. They understand the necessary modeling paragraphs and can assess the results. They can apply the theoretical basics they have learned to real technical systems.
Social skills:
In the exercises accompanying the lectures, the students learn how to independently calculate technical design data for renewable energy systems. If they have problems, they can ask your fellow students or the lecturer.

Content:

1. Introduction and Thermodynamic Basics
2. Energy Transformation and Sources
    a. Solar
    b. Wind
    c. Hydro

d. Biomass
e. Geothermal

3. Energy Storage
   a. Hydrogen
   b. Thermal
4. Selected Operation Units

Literature:

- Quaschning, V. (2016). Understanding Renewable Energy Systems. In Understanding Renewable Energy Sys-tems. Routledge. https://doi.org/10.4324/9781315769431
- Stolten, D., & Emonts, B. (2016). Hydrogen Science and Engineering : Materials, Processes, Systems and Technology (Vols. 1–2). Wiley-VCH Verlag GmbH & Co. KGaA. https://doi.org/10.1002/9783527674268
- Dinçer, İ., & Rosen, M. A. (2021). Thermal Energy Storage. Wiley. https://doi.org/10.1002/9781119713173
- Leipertz, A. (2011). Technische Thermodynamik für Maschinenbauer, Fertigungstechniker, Verfah-renstech-niker und Chemie- und Bioingenieure (4. Aufl.). ESYTEC.
- Lund, P. D., Byrne, J., Haas, R., & Flynn, D. (2019). Advances in Energy Systems: The Large-scale Renewable Energy Integration Challenge. Wiley. https://books.google.de/books?id=cA6GDwAAQBAJ

German I

Module abbreviation:	SES-German I	**Reg.no.:**	6
Curriculum:	**Programme**	**Module type**	**Semester**
	Smart Energy Systems (SPO WS 21/22)		1

Responsible for module:	Jungwirth, Johannes
Lecturers:	Baudracco-Kastner, Monica
Language of instruction:	German/English
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 45 h Self-study: 105 h Total: 150 h
Subjects of the module:	6: German I (SES-German I)
Lecture types:	Seminar-based teaching
Examinations:	6: project work, 10 pages (SES-German I) Prerequisite for granting credit points is that the respective module examination is passed in accordance with the SPO and study plan.

Prerequisites according examination regulation:

According to study and examination regulations and study plan

Recommended prerequisites:

None

Objectives:

Technical and methodological competence:

The students get the communication basics for everyday life in Germany and for their studies. Through practicing of speaking and writing they get insights into the German culture and language and consolidate their previous knowledge. They expand their knowledge of vocabulary and structures of the German language and improve their pronunciation by getting confident with the sound, the rhythm and melody of the foreign language.

Professional action competence:

The students are able to master simple communicative situations in German. They understand dialogues and basic information regarding everyday´s life and can interact and speak about their personal experience and their needs.

Social skills:

The students gain self-confidence for interaction in German in different situations outside the classroom and improve also general communications skills like active listening, empathy, interaction in groups. They get familiar with the German culture and “way of life”, so that they can feel at home in the new environment.

Content:
The students bring their topics, moods and situations into the lectures. In framework activities that alternate individual support and work group, they practice and improve their language and communication skills. In the following reflection phase, they get theoretical impulses to the grammar and language structures and their questions are answered. The assimilation of the new skills takes place through practicing the language in authentic situations outside the classroom.
Literature:
• DENGLER, Stefanie and others, 2020. *Netzwerk neu A2.2: Kursbuch mit Audios und Videos*. 1. edition. Stuttgart: Ernst Klett Sprachen. ISBN 978-3-12-607164-2

2.3 Wahlpflichtmodule II

German II

Module abbreviation:	SES-German II	**Reg.no.:**	12
Curriculum:	**Programme**	**Module type**	**Semester**
	Smart Energy Systems (SPO WS 21/22)	elective module	2

Responsible for module:	Jungwirth, Johannes
Lecturers:	Baudracco-Kastner, Monica
Language of instruction:	German/English
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 45 h Self-study: 105 h Total: 150 h
Subjects of the module:	12: German II (SES-German II)
Lecture types:	Seminar-based teaching
Examinations:	12: projekt work, 10 pages (SES-German II) Prerequisite for granting credit points is that the respective module examination is passed in accordance with the SPO and study plan.

Prerequisites according examination regulation:

According to study and examination regulations and study plan

Recommended prerequisites:

None

Objectives:

Technical and methodological competence:

The students are proficient in communication in German, in a private as well as in a professional environment. They are familiar with different kind of written texts (newspaper articles, literature, e-mails and social media...) and acquainted with typical business situations with their specific language and social rules.

Professional action competence:

The students develop the ability to communicate appropriately and professionally in typical situations in private and public life. They connect to the topics of their SES studies and learn to discuss and present them in German. They acquire the competences to present a known topic to an audience and to take part to discussions expressing in a simple way their opinions and argumentations.

Social skills:

The students learn to communicate clearly and intelligibly in German. They build communication capabilities for different situations and are able to work in a group interacting in German. They develop awareness for intercultural differences and can communicate in an appropriate way according to the given context.

Content:

The focus is on interaction and group work on given topics. In an action phase the students practice the written and spoken language and various communications skills. In the reflection phase they analyze the used language with the support of the trainer and get theoretical impulses to improve and strengthen their proficiency in communication in German.

Literature:
• DENGLER, Stefanie and others, 2021. *Netzwerk neu B1.2: Kurs- und Übungsbuch mit Audios und Videos*. 1. edition. Stuttgart: Ernst Klett Sprachen. ISBN 978-3-12-607171-0, 978-3-12-607191-8

Photovoltaics Engineering

Module abbreviation:	SES-PhotovoltaicsEngineering	**Reg.no.:**	12
Curriculum:	**Programme**	**Module type**	**Semester**
	Smart Energy Systems (SPO WS 21/22)	elective module	2

Responsible for module:	Rosenbauer, Georg
Lecturers:	Rosenbauer, Georg
Language of instruction:	English
Credit points / SWS:	5 ECTS / 4 SWS
Workload:	Contact hours: 45 h Self-study: 105 h Total: 150 h
Subjects of the module:	12: Photovoltaics Engineering (SES-PhotovoltaicsEngineering)
Lecture types:	Seminar-based teaching
Examinations:	12: written exam, 60 minutes (SES-PhotovoltaicsEngineering) Prerequisite for granting credit points is that the respective module examination is passed in accordance with the SPO and study plan.

Prerequisites according examination regulation:

According to study and examination regulations and study plan

Recommended prerequisites:

None

Objectives:

Technical and methodological competence:

The course is based on self-conducted experiments and investigations executed partly in labs, partly as outdoor research. Students not only learn to use different lab measuring devices but also how to handle typical measurement tools that are in practical use with the photovoltaics industry. Students learn to design a simple software-based plant layout and evaluate its economic efficiency. They get familiar with widely-used software in the field of photovoltaics.

Professional action competence:

Presentation skills: Experiment results will regularly be presented and discussed in plenary sessions. Thus the students' ability to give presentations will be improved.

Lab skills: During the entire workshop, a range of typical measurement devices (partially not PV-specific) will be used.

Social skills:

The experiments are done in self-organised teams with 3 to 4 students. Coordination, joint decision making and discussions of experiment results strengthen the social skills.

Content:

- Solar insolation, Three-Component-Model
- Measurement of U-I curves using different methods

- Evaluate the Performance Ratio of an outdoor PV setup
- Analysis of the effects of partial shadowing scenarios
- Evaluation of potential locations for application
- Plant design with regard to technical and economical aspects
- Evaluation of data gained from a commercial photovoltaic plant, fault analysis
- IR-based fault analysis of single modules

Literature:

- MERTENS, Konrad, 2019. *Photovoltaics: fundamentals, technology, and practice*. S. edition. New York: Wiley. ISBN 978-1-119-40104-9