Course description

Course title: **Engineering of Sustainable Stationary and Transportation Energy Systems**

Hours per week: 20h/week, 2 weeks

Number of credits recommended/ work load:

a) 40 contact hours

b) 3 US Quarter credits

c) 3 ECTS credits

Course description:

Engineering of Sustainable Energy Systems enables engineers to analyse, design and optimize sustainable energy systems. The course introduces students to sustainable clean energy technologies and systems engineering methods for stationary and transportation systems (grids), including solar and wind power (sub-) systems and renewable fuels.

The course consists of two parts:
Part I covers methodological aspects for understanding, designing and optimizing sustainable energy systems. This includes a system related overview on key components of energy conversion and storage as well as their sustainable system integration alternatives.

Part II reviews technical options and the engineering of solar PV and wind power systems, and alternative fuels and electric propulsion for automobiles. Basic knowledge of chemistry and physics (power and energy) is recommended for analysis of selected energy sources and fuels.

Course Content:

A) The need for sustainable energy systems and their architecture

- Primary and final energy demands
- Sustainability, availability of resources and ecological balance
- Structure and behaviour of a sustainable energy system and how to evaluate it
- Key Performance Indicators of sustainable energy systems
- Key components (a) primary energy converters (wind, solar, hydro)
- Key components (b) energy storages (electrical, mechanical, thermal, chemical)

B) Systems Engineering approaches for sustainable systems

- The V-Model for engineering of complicated and complex systems
- Basics of systems analysis, design, implementation and test
- Model based engineering – applying models and simulation on sustainable systems
- Modelling and simulating sustainable energy systems
- Analysing and optimising sustainable energy systems

C) Technologies and engineering of sustainable transportation systems

- Alternative energy options for automobiles: renewable fuels, battery-electric, hybrid battery/ICE and fuel cells
- Renewable fuels defined with examples
- Primary energy sources vs energy carriers
- The internal combustion engine, and how it performs with different fuels
- CO2 neutral energy sources and cycles
- Transportation energy infrastructure requirements
- Comparison of efficiency and power output for various practical alternative fuels.
- Comparative greenhouse gas generation for different transportation energy options.
- Comparative efficiency and power output for different automotive alternative fuels.

D) **Technologies and engineering of solar PV and wind power systems**

- Photovoltaic cells and modules: electrical modelling and system design
- Small-scale solar photovoltaic power systems
- Interfacing PV systems with the utility grid and local electrical loads
- Grid-tie systems: Theory, design and regulations
- Off-grid systems: Theory, design, and local energy storage
- Hybrid solar systems: grid-connected with battery storage
- Cost recovery analysis for solar PV systems
- Commercial-scale wind power – technology and integration with the power grid
- New challenges of distributed power generation

Course Learning Objectives and Expected Outcomes:

- Understand basics of sustainable developments.
- Recognize and articulate the significance of issues related to global energy and the environment.
- Understand fundamental topology of sustainable energy systems and their key components for primary energy conversion and storages.
- Follow a methodological engineering approach for defining, designing, implementing and testing.
- Be able to identify best sustainable system solutions within given use case scenarios.

- Understand basics of modelling and simulating sustainable energy systems.
- Be able to define and quantify key performance indicators of energy systems.
- Understand system structure and behaviour based on models and simulation.
- Be able to select and compare different automotive and transportation energy options in terms of their energy and environmental sustainability.
- Understand the operation of an internal combustion engine to the level required to understand fuel combustion and emissions.
- Knowledge of transportation fuelling infrastructures, including the electric grid.
- Understand capabilities, features and basic operation of photovoltaic (PV) facilities.
- Distinguish PV and thermal solar power systems and their related technologies.
- Compare and specify different types of photovoltaic modules, including configurations, environmental requirements, electrical protection methods, and performance attributes.
- Knowledge of battery-storage options for residential-scale gird-tied solar PV systems.
- Understand the fundamentals of wind power technologies.
- Become aware of integration issues with distributed and non-constant generation systems, and the ramifications for the electric grid.

Prerequisites:

- Any engineering or physical science major.
- Basic knowledge of chemistry and physics.
- Interest in energy and environmental sustainability.

Recommended reading:

- F. Vanek et al.: “Energy Systems Engineering: Evaluation and Implementation”, McGraw-Hill, 3rd edition, 2016
- INCOSE: “Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities”, Wiley, 4th edition, 2015
- Karl Heinz Dietsch and others, “Automotive Handbook, 10th edition. Published by Robert Bosch GmbH, distributed by Society of Automotive Engineers (SAE), 2018.

Teaching methods:

- Blending of lecture presentations with in-class and external exercises

Assessment methods:

- 10% Current topics student presentations
- 90% Final Exam

Language of instruction:

- English

Name of lecturers:

- Prof. Dr. Herbert Palm (MUAS)
- Prof. Dr. Art MacCarley (California Polytechnic)