PREREQUISITES:

- Bachelor of Science in Technology
- Knowledge of sustainable development and system analysis corresponding content in courses MJ2413 "Energy and Environment" or MJ2508 "Energy Systems for Sustainable Development"
- Knowledge of Linear Algebra, corresponding content in course SF1624 "Algebra and Geometry"

OVERALL OBJECTIVE:

The overall objective of this course is to provide the student with solid ground knowledge of Energy Systems Modelling theory and its application to problems of sustainable development planning. Focus is on the creation from scratch and understanding of an energy system model and its underlying dynamics.
The course builds on the skills and competences created in MJ2413 Energy and Environment, especially those related to systems thinking. It starts from the same definition of 'system', but then dives into how an energy system, its internal dynamics and its relation to other systems can be modelled. Linkages with biophysical systems (such as water and land) will also be modelled, to analyse quantitatively selected trade-offs between Sustainable Development Goals.
Students will apply all concepts in the final 3 credits project, which, if of sufficiently high quality, will provide an input to ongoing collaborations between KTH, the UN and national governments to support national Climate Mitigation and Adaptation planning.

ILOs:

Upon successfully completing this course, the student will be able to:
1. Describe common energy systems modelling and scenario analysis approaches and identify their key strengths and limitations.
2. Write a linear energy system optimization problem.
3. Apply a selected energy systems modelling tool in the analysis of stylized long-term energy planning problems.
4. Analyze various sample energy system situations and appropriately distill insights, given limited and uncertain information.
5. Include a basic representation of the links between climate, land use, energy and water into an energy system model.
6. Undertake a thorough and detailed analysis of a selected national energy system, including independent data gathering, problem definition, model choice, generation of solutions and interpretation.

Course content:

The course structure consists of 5 lectures and 6 computer labs. Most of the lectures are designed as flipped classrooms: students are given small tasks in preparation for the lectures and work in groups and with the teacher during the classes, to extract insights and learning outcomes on the relevant topic.
For the labs, students work individually or in groups in a number of exercises where they apply the concepts discussed in class. The group work is a fundamental part of the learning experience in this course and the students are expected to find ways to collaborate, learn jointly and balance fairly the load in the group.
The examination is based on several assignments, that directly come from outputs of the lectures and labs, and on the 3 HP project.
Ad-hoc sessions for introducing the project and for Q&A on the project are scheduled.
Below and overview of the topics, by lecture and lab.

Lecture 1 – Introduction to energy system Analysis:

What is it needed for? How does it support sustainable energy planning?
What is an energy system and how can it be represented?
What does sustainability mean in the context of an energy system and how can it be measured?
What are energy system models needed for? What is their role in supporting sustainable energy planning?

Lecture 2 – Types of energy system modelling tools:

Bottom-up and top-down modelling tools
Categorisation of energy modelling tools
Long-term optimisation modelling tools

Lecture 3 - Modelling selected impacts of the energy system and the environment, economy and society

Modelling impacts on the economy (e.g. job creation)
Modelling links with climate
Modelling the water-energy-food nexus

Lecture 4 - Scenario analyses

Types of scenario analyses used in energy systems analysis (normative, explorative, predictive)
Examples and outcomes of published scenario analyses

Lecture 5 - Use of models in technical assistance programs to shape the global agenda

Use of open source energy and integrated modelling tools in technical assistance programs for government officials, in collaboration with Development Partners. Case studies, success and challenges.

Lab 1 - Designing an energy system optimization problem

Structure of linear optimization energy system models
Creating the algebraic formulation of a linear optimization energy system model from scratch, with inclusion of economic and environmental constraints

Lab 2 - Studying the working principles of a sample energy system model

Group work with OSeMOSYS and an interface designed for it, to create and and analyse the dynamics of a sample energy and system model. Windows 10 operating system is required to install the interface, but if not possible the students will have access to the interface in the lab computers or will have access to an online version of the interface.

Lab 3 – Debugging a model

Hands-on group work together with the tutors on how to debug a model, starting from problems encountered in Lab 2 and extracting experiences and tips. When building models, mistakes happen always, even to the best modellers. Mistakes lead to malfunctioning of the model and/or incorrect results. Tracing the mistakes is not always easy, it can take time and be frustrating. Yet, there are ways to make the search faster and to extract great learning from the experience.

Lab 4, 5 – Extending the sample energy system model with representations of the climate, water and land use systems

Group work on the model completed in Lab 2 and debugged (if necessary) in lab 3. The exercise will aim at identifying the cause-effect relations between investment and operation decisions in the energy, agricultural and water supply sector.

Lab 6 - Scenario analysis with a sample climate, land, energy and water model

Group work on the model completed in Lab 5. The exercise will aim at creating and analysing different least-cost transformation paths for the energy, land and water systems.

<u>ASSESSMENT AND GRADING CRITERIA:</u>

Following, the ILOs are related to grading outcomes.

ILO 1: Describe common energy systems modelling and scenario analysis approaches and identify their key strengths and limitations.

Assessed in PRO1 – 1.5 HP: Continuous assessment from individual reflections after lectures

- E: The student can describe common energy systems modelling and scenario analysis approaches;
- C: The student can identify key strengths and limitations of different common energy systems modelling and scenario analysis approaches in light of sustainable planning challenges;
- A: The student can identify key strengths and limitations of different common energy systems modelling and scenario analysis approaches and reflect upon their importance in sustainable energy planning;

ILO 2: Write a basic linear energy system optimization problem.

Assessed in PRO2 – 1.5 HP: Individual assignment

- E: The student has written and successfully run the optimization function and demand-supply constraint of a basic energy system optimization problem, upon being provided a text description;
- C: The student has written and successfully run all the equations of a basic energy system optimization problem with economic and environmental constraints, upon being provided a text description;
- A: The student has written and successfully run all the equations of a basic energy system optimization problem with economic and environmental constraints, upon being provided a text description, has run suggested scenarios and has reflected upon the differences in the results;

ILO 3: Apply a selected energy systems modelling tool in the analysis of stylized long-term energy planning problems.

Assessed in PRO3 - 1.5 HP: Group assignment

- E: The student has created a simple energy system model, following given instructions, and has obtained results;
- C: The student has created a simple energy system model, following given instructions, has obtained results and comprehensively answered key questions posed by the tutors;
- A: The student has created a simple energy system model, following given instructions, has obtained results and has reflected upon the dynamics underlying those results, with the help of sensitivity analyses.

ILO 4: Analyze various sample energy system situations and appropriately distill insights, given limited and uncertain information.

Assessed in PRO3 (see ILO3) and in PRO4 – 1.5 HP: Group assignment

- E: The student has modelled and obtained results for a set of pre-defined scenarios and has commented on how reasonable each result is;
- C: The student has modelled and obtained results for a set of pre-defined scenarios, has commented on the implications of each result for sustainable energy planning and has provided relevant comparisons between independently selected scenarios;
- A: The student has modelled and obtained results for a set of pre-defined scenarios, has commented on the implications of each result for sustainable energy planning, has provided

relevant comparisons between independently selected scenarios and has successfully created one additional scenario aiming at sustainable energy development.

ILO 5: Include a basic representation of the links between climate, land use, energy and water into an energy system model.

Assessed in PRO4 – 1.5 HP: Group assignment

- E: The student has modelled and obtained results on water and land use impacts of a sample energy system for situations already conceptualised externally;
- C: The student has modelled and obtained results on water and land use impacts of a sample energy system for situations already conceptualised externally and has commented on them;
- A: The student has modelled and obtained results on water and land use impacts of a sample energy system for situations already conceptualised externally, has commented on them, has compared them where relevant and has critically analysed the interlinkages (including trade-offs and synergies) between water – land use and energy systems.

ILO 6: Undertake a thorough and detailed analysis of a selected national energy system, including independent data gathering, problem definition, model choice, generation of solutions and interpretation.

Assessed in PRO5 – 3 HP project: Group assignment

- E: The student has carried out a well-balanced shared of a group project, contributing to the successful creation of a country energy system model;
- C: The student has carried out a well-balanced shared of a group project, contributing to the successful creation of a country energy system model and actively contributing to the critical analysis of the results and their implications for sustainable development;
  A: The student has carried out a well-balanced shared of a group project, contributing to the successful creation of a country energy system model from the start, actively contributing to the critical analysis of the results and their implications for sustainable development and creatively adding novel elements to the model.

EXAMINATION:

ILO 1 is assessed on a continuous basis, through PRO1;

ILO 2 is assessed through one mandatory 1.5 HP individual assignment – PRO2.

ILO 3 is assessed through one mandatory 1.5 HP group assignment – PRO3.

ILO 4 is assessed through two mandatory 1.5 HP group assignments – PRO3 and PRO4.

ILO 5 is assessed through one mandatory 1.5 HP group assignment – PRO4.

ILO 6 is assessed through a 3 HP group project, culminating in the mandatory submission of a final project report (PRO5).

Requisites for passing the course (on top of the grading criteria described above) are:

- Submit the 4 1.5 HP assignments and the 3 HP project report by the deadline and obtain a minimum grade of E for each.
- Extension on the deadline can be given under special circumstances, e.g. due to illness as documented by an official certificate issued by a physician. You need to obtain an approval of extension from the examiner BEFORE the deadline.
- Failure to meet the deadline leads to only the possibility of obtaining the grade E upon submission, and provided that the project is judged of passing quality. If you want to have the opportunity to obtain a higher grade, you need to re-register for next years' course round and project.

Final grade = 0.67*Average of (PRO 1-4) grade + 0.33*(PRO 5) grade.

	PRO1	PRO2	PRO3	PRO4	PRO5
ILO1	X (A-F)				
ILO2		X (A-F)			
ILO3			X (A-F)		
ILO4			X (A-F)	X (A-F)	
ILO5				X (A-F)	
ILO6					X (A-F)

- For the purpose of computing the average above, conversions of the Letter grades of individual assignments into numbers are made. The conversions are as follows: A = 0.45; B = 0.35; C = 0.25; D = 0.15; E = 0.05. If the resulting average is > 0.4, the final course grade is A; if it is > 0.3, final grade is B; if it is > 0.2, final grade is C, if it is > 0.1, final grade is D; if it is > 0, final grade is E. If the resulting average is exactly 0.4, 0.3, 0.2, or 0.1, the grade will be respectively B, C, D and E.