



# MJ2380 Introduction to Energy Systems Analysis and Applications, 9 ECTS

## Course Syllabus 2025

Welcome to this course on Energy Systems Analysis and Applications, an engineering science course where we aim to provide you with learning activities to form a solid ground knowledge of Energy Systems Modelling theory and its application to problems of sustainable development planning. This includes creating from scratch and understanding energy system models and their underlying dynamics. You will be working with questions like “How can Energy System Analysis support planning for sustainable development?”, “What types of tools exist to carry out the analysis?”, “How do I design an Energy System Optimization problem”, “What do specific results of an Energy System Optimization model tell me, considering the assumptions I had to make”?

### *On Energy Modelling ...*

*“Energy modelling and policymaking have been closely linked for most of the last five decades, ... These models essentially track how the energy system responds to shifts in energy supply or demand conditions brought about changed economic, environmental, technical or policy conditions.”<sup>1</sup>*

In the course, we work with a mixture of lectures, computer labs and digital learning activities for self-study, with home assignments and oral presentations carrying the examination, but also support your learning. The content of the course is close to our research and linked to activities we carry out in developing contexts in collaboration with the United Nations, which is why several teachers and experts, in addition to the course coordinator and examiner, are involved in the implementation of the course.

Topics include the structure of linear optimization energy system model, creating and designing an energy system model from scratch, and analysing the underlying dynamics within and modelling selected impacts of the energy system on the environment, economy, and society.

Overall, the examination of the course is organized through four projects:

- HEM1 (1.5 ECTS and individual submission),
- HEM2 (1.5 ECTS and individual submission),
- HEM3 (3 ECTS, and individual submission),
- TEN1 (3 ECTS, group project work, group submission of a model brief, and individual oral examination).

In addition to being examination activities, these modules drive your learning with a clearly designed path among all topics.

---

<sup>1</sup> Huntington, H.G., 2021, “ Model evaluation for policy insights: Reflections on the forum process”, Energy Policy, <https://doi.org/10.1016/j.enpol.2021.112365>

## Learning Outcomes

After completing the course, the student will be able to:

1. Evaluate common energy systems modelling and scenario analysis approaches and critically discuss their key strengths and limitations in addressing Sustainable Development issues.
2. Design a linear energy system optimization problem with economic and environmental constraints.
3. Apply a selected energy systems modelling tool to analyse stylized long-term sustainable energy planning problems.
4. Analyze various sample energy system situations and appropriately distil insights, given limited and uncertain information.
5. Design and construct a thorough and detailed analysis of a selected national energy system, including independent data processing, problem definition, generation of solutions and interpretation of the results considering the country's Sustainable development challenges.
6. Analyse the links between climate action, land use, energy infrastructure development and access to clean water in an energy system model and discuss solutions for coherent planning concerning real-world challenges.

## Pre-requisites

As specific requisites, aside from having a relevant BSc degree (this is a 2<sup>nd</sup> cycle, master-level course) we expect you to have knowledge of sustainable development and system analysis (e.g., corresponding content in the courses MJ2413 "Energy and Environment" or [MJ2508](#) "Energy Systems for Sustainable Development"), as well as of Linear Algebra (e.g., corresponding content in course SF1624 "Algebra and Geometry"), Linear Programming and Optimization. For your convenience, we have organized some self-study modules within CANVAS to allow you to brush up on these matters and assess your status as follows:

- Self-study module: World Energy Outlook, Global Dynamics, and SDG interlinkages
- Self-study module: Integrated assessment – the NEXUS perspective and Climate-Land-Energy-Water Modelling.
- LAB0: Linear Programming and Optimization – a “brush up”.

In all the course activities, from the start, **we expect you to master this material.** Do not hesitate to ask questions as you go through it.

## Learning Resources

Reading material will be handed out per lecture/lab and collected in the course event on CANVAS. Please note that each lecture and lab comes with some suggested literature and sometimes other preparations or deliverables after the class meeting. Please refer to the detailed lecture plan for more information.

The energy systems modelling tool used in this course is the fully open-source modelling tool for long-term integrated assessment and energy planning [OSeMOSYS](#). Those of you who have worked with the tool in MJ2508 will have a chance to dig deeper into its use in MJ2380 by *building simplified and more complex applications from scratch, understanding the impacts of a large array of parameters on the insights that can be derived, and understanding the*

*underlying code base of the tool.* Those of you who have not used OSeMOSYS before need not worry, you'll be taken through it step-by-step.

## **Examination and Grading**

- HEM1 – Individual Project; 1.5 credits; A, B, C, D, E, Fx, F
- HEM2 – Individual Project; 1.5 credits; A, B, C, D, E, Fx, F
- HEM3 – Individual Project; 3.0 credits; A, B, C, D, E, Fx, F
- TEN1 – Individual oral examination, 3.0 credits, grading scale: A, B, C, D, E, FX, F

### ***Individual project 1, HEM1***

This project examines your learning specifically related to the topics covered by the first two lectures, with accompanying Lab 1 (and other related supporting sessions). You will create, following step-by-step instructions provided by us, a simple energy system modelling application using a User Interface for OSeMOSYS (called 'MUIO' – Model User Interface for OSeMOSYS). The purpose of going step-by-step is developing an understanding of how the introduction of different datasets changes the insights you can get from the results. Knowing well how the model you create behaves is a must when you embark with modelling. **You will be asked to reflect on that and you will be assessed specifically on the reflection.**

The application allows you to familiarize with the tool, make use of all the input parameters normally employed in the creation of an energy system model, understand the type of input data needed for creating a model. Follow the steps with care, timely, and try to understand what you are doing: the application is designed to help you also with the creation of your country model for the group work, which will start (not casually) almost in parallel.

You may encounter problems on the way, for example 'bugs' in your model. To help you through those, Lab 2 will give you tips on how to find and correct bugs. Also this will come very handy for the work for TEN1, so make treasure of it.

You may also be interested to know that this simplified application is the exact same we use together with the United Nations Department of Economic and Social Affairs (UNDESA) to train government officials around the world in creating energy systems models for supporting their national strategies (and NDC updates). If you are interested in becoming an energy analyst as a next carrier step, the learning from this assignment will take you quite some way there!

Specifically, after the completion of this project, you will be able to:

- ***Using OSeMOSYS, complete and assess an simple energy system model.***

Upon completing this project, you are well prepared to contribute to the modelling tasks for the group modelling work for TEN1 and for HEM3.

More instructions on HEM1, including the grading criteria, will be provided in a separate *instruction published on CANVAS HEM1 "module"*. **Look carefully at the grading criteria!** You are assessed specifically on those, so if you do many things well but these are not part of the grading criteria you will be penalized.

Your work is examined via a brief assignment report (where you will compile your results and answer a set of reflection questions) with **submission deadline on Monday, Feb 10 at 17:00 hrs (SHARP) via CANVAS.**

## **Individual Project 2, HEM2**

In this individual project, you will look ‘behind the curtains’ of the User Interface you used for HEM1. The aim is for you to understand more in-depth how an energy system optimization model works, what happens when you introduce one constraint or another, what its limitations are, why there is a certain relation between inputs you give and results you obtain. This is essential for you to be able to explain what a model you created actually does, and what type of analysis it is suited *or not suited* for.

You will work with the code and structure of OSeMOSYS. You will be asked to explain what different equations of the code of OSeMOSYS mean, and why they are important. Again, the lectures and lab activities will guide you through the necessary learning. In Lecture 3 you will receive all the theoretical foundations of OSeMOSYS and energy systems optimization you need. In Lab 3 you will create the code for a very simple energy system model from scratch, to familiarize with its structure and the formal language used. Then in Lab 4 you will dive into the task of working with and understanding the equations of OSeMOSYS.

Even though the Lectures and Lab activities are designed to facilitate your learning, for your learning in this assignment to be smooth and full **you need** some basic knowledge of linear programming and of energy systems. Check if you have such knowledge in advance, through the preparatory material on Linear Optimization that we provide, and **get back to us if you are struggling** with those concepts or those from the first lectures of the course.

Specifically, after the completion of this project, you will be able to:

- *Explain the structure of an energy system optimization model and propose modifications to it.*

More instructions on HEM2, including the grading criteria, will be provided in a separate instruction published on CANVAS HEM2 “module”. **Look carefully at the grading criteria!** You are assessed specifically on those.

Your work is examined via a brief assignment report with **submission deadline on Tuesday April 15 at 17:00 hrs (SHARP) via CANVAS.**

### **Group Project + Individual oral examination, TEN1**

This 3-credit project is a group project with **individual oral** examination, where you are expected to demonstrate that you have achieved the objective of the course, i.e. that you have developed solid knowledge about Energy Systems Analysis theory and practice and that you have a deep understanding of how an energy system model works. The Open Source Energy Modeling System (OSeMOSYS) will be used as the modelling framework for the project, as one important example of a long-term fully open-source optimization model suitable for energy planning and integrated assessment. If you aim at becoming an energy analyst by profession, this learning experience will equip you well for the task!

More specifically, each group will investigate one country as a case application, among a selection of countries provided by the teaching team. For the country chosen, each team will collect the necessary data, create a model and create scenarios for an **electricity system** analysis for long-term planning. Among other things, an objective will be to assess pathways to fulfil the country’s Nationally Determined Contribution (NDC) plan until 2030 and beyond.

All the modelling and reporting work will be carried out in groups (**of max 4 people**), but the final assessment will be oral and individual. That is, each student will need to be able to answer questions on the model's structure, results and insights and on the overall context and messages individually, during an oral examination. Specifically, the milestones leading to the assessment will be the following:

- Mandatory, ungraded submission of a group project plan early on;
- Mandatory, ungraded submission of a draft project factsheet (i.e. a few-pages brief succinctly outlining context, need, scope of the analysis, model structure, key datasets) and excel file with the core datasets;
- Mandatory, ungraded group presentation of the whole project, in a plenary session with the whole class;
- Mandatory, ungraded submission of the final project factsheet (including, on top of all the previous elements, results and discussion of key policy-relevant insights);
- **Graded individual oral examination.**

Note that all the mandatory, ungraded group milestones leading up to the graded individual examination are meant as occasions for you to 1) shape up your work, 2) learn by getting ungraded feedback, 3) prep for the final oral exam.

More instructions on TEN1, including the grading criteria, will be provided in a separate *instruction published on CANVAS TEN1 "module"*.

***Important dates for this project are as follows:***

Jan 16 (Thu), 10-12, V1/ZOOM: TEN1 and group project introduction

Jan 20 (Mon) at 17:00 hrs - deadline: Group Formation via CANVAS sign-up in a group

Jan 28 (Tue), 15-17, ZOOM: first project interaction with tutors (one link, breakout rooms)

Feb 6 (Thu) at 17:00 hrs – deadline: group project plan deliverable

Feb 11 (Tue), 13-15, ZOOM: Project plan formative feedback (one Zoom link, breakout rooms)

Feb 26 (Wed), 13-17, M3: Interim Project Presentations 1(2), in person (ZOOM only for students who cannot join)

Feb 27 (Thu) 13-17, M3: Interim Project Presentations 2(2), in person (ZOOM only for students who cannot join)

Mar 5 (Wed) at 17:00 hrs – deadline: draft of project factsheet

Mar 18 (Tue), 13-15, ZOOM: Project interaction

Mar 28 (Fri), 10-12, ZOOM: Project interaction

Apr 9 (Wed), 10-12, ZOOM: Project interaction

May 9 (Fri), 10-12, ZOOM: Project interaction

May 16 (Fri) 8-12, M3: Final Project Presentation 1(2), in person (ZOOM only for students who cannot join)

May 20 (Tue) 13-17, V1: Final Project Presentation 2(2), in person (ZOOM only for students who cannot join)

June 5 (Thu) at 17:00 hrs – deadline: project factsheet submission (Group)

June 9 to 19: TEN1 Oral examinations (students to sign up for slots on Canvas calendar – 30 minutes for 2 students)

### **Individual project 3, HEM3**

In this individual assignment, you will learn about some links that exist between the climate, land, energy and water systems and why it is important to consider them in planning for sustainable development.

In practice, you will continue your individual work from HEM1, to extend the sample energy system model you created then with representations of the climate, water, and land systems and then carry out limited scenario analyses with the model. You will start from the final model of HEM1, use MUIO and follow again step-by-step instructions. This exercise will require quite some effort of abstraction, because you will not be adding parts of the electricity supply chain (power plants and fuels) to the model, but entirely different objects (land uses, water supply technologies, etc.). This will take you out of the domain of energy, to deal with different concepts, different sciences and different quantities / units of measurement. The exercises will also become more articulated, the model heavier, the bugs more difficult to find. The reflections on the model results and what they communicate will be more profound. That is why the assignment gives you 3.0 ECTS (double credits compared to HEM1). Lecture 4 will give you the theoretical foundations necessary for this assignment, while Lab 5 and Lab 6 will take you through that hands-on tasks at hand.

Specifically, after the completion of this project, you will be able to:

- ***Identify the cause-effect relations between investment and operation decisions in the energy, agricultural, and water supply sectors, as applied to various scenarios.***

More instructions on HEM3, including the grading criteria, will be provided in a separate instruction published on CANVAS HEM3 “module”. **Look carefully at the grading criteria!** You are assessed specifically on those.

Your work is examined via a brief assignment report (where you will compile your results and answer a set of reflection questions) with **a submission deadline of May 12, 17:00 hrs (SHARP), via CANVAS.**

### **Course Final Grade**

The final grade on the course will be a credit-weighted average of the grades obtained in HEM1, HEM2, HEM3 and TEN1.

To compute the average, the Letter grades of individual assignments are converted into numbers. The conversions are as follows:

E=1, D=2, C=3, B=4, A=5.

If the resulting average is greater than or equal to 4.5, the final course grade is A; if it is greater than or equal to 3.5, the final grade is B; if it is greater than or equal to 2.5, the final grade is C; if it is greater than or equal to 1.5, the final grade is D; if it is greater than or equal to 0.5, final grade is E.

Some examples of the weighted average:

- i. HEM1 grade E; HEM2 grade C; TEN1 grade B; HEM3 grade E; gives the weighted avg =  $(1.5*1+1.5*3+3*4 + 3*1)/9 = 2.3$  which then translates to a D.

- ii. HEM1 grade A; HEM2 grade A; TEN1 grade C; HEM3 grade B gives the weighted avg =  $(1.5*5+1.5*5+3*3+3*4)/9 = 4$ , which is then translates to a B.

## Compensatory support for students with disabilities during examination

For students with disabilities who have a statement from KTH's FUNKA unit on recommended support during examination, the following applies in this course:

- All support under code R (i.e. adjustments relating to space, time and physical circumstances) are granted without special decision by the examiner.
- Support under code P (educational adaptation) must be actively granted or rejected by the examiner **after the student has made contact** in accordance with KTH's rules. Usually, support actions under code P will also be approved.

**Therefore, if you have support under code P please do reach out to the Examiner well in advance of the examination moments.**

## Contacts

*Course responsible*

Dr Francesco Gardumi

*Examiner*

Professor Viktoria Martin

*Course teachers*

Dr Francesco Gardumi

MSc Emir Fejzic

MSc Shravan Kumar

*Project and lab tutors*

MSc Emir Fejzic

MSc Camilla Lo giudice

MSc Shreyas Savanur

Diki Darmawan

Godswill Ifeanyi

Please always contact any of us **via the CANVAS message system** (and we can decide on a meeting time or other, as needed). Using our regular e-mails might result in a longer time for answers.