46770 Integrated energy grids

Marta Victoria

Course description

Introducing the lecturing team

Marta Victoria

Associate Professor of Solar Photovoltaics and Energy Systems Modelling

Technical University of Denmark

I am an Associate Professor at the Department of Wind and Energy Systems at DTU and I keep a small affiliation at the Department of Mechanical and Production Engineering at Aarhus University. My research focuses on the modelling of large-scale energy systems with high renewable penetration paying special attention to the role of solar photovoltaics and the design of resilient energy systems.

I obtained my BSc and MSc in Aerospace Engineering at the Technical University of Madrid where I also got my PhD in high-efficiency photovoltaic modules at the Solar Energy Institute.

Currently, I lead the EXTREMES project where we investigate the impact of extreme weather events on energy systems and I implement system modelling to research the role of CO2 capture and conversion technologies within the NNF CO2 Research Center. Moreover, I participate in the HYPERFARM project, where we investigate different Agrivoltaic concepts and I lead Aarhus University's participation in the AURORA project where we are establishing energy communities at four major technical universities in Europe. In the past, I have participated in the REINVEST project to research alternative transition pathways for Europe and Denmark.

I am a member of the Open Energy Modelling Initiative, which aims to promote openness and transparency in energy system modelling, and I co-develop the open-source energy model PyPSA-Eur.

Introducing the lecturing team

Alexander Grochowicz
(Postdoctoral researcher)
will contribute to lectures

Lukas Karkossa (PhD student)

will be teaching assistant (TA)

Marco Saretta (PhD student)

will be teaching assistant (TA)

Lectures routines

8:00 - 8:45	Marta lectures on the topic of the day
8:45 - 9:00	Break
9:00 - 9:45	Marta keeps lecturing on the topic of the day
9:45 - 10:00	Break
10:00 – 10:45	Solutions from problems proposed in the previous lecture are presented by a group of students
10:45 -12:00	Time to work on the problems proposed for the topic of the day. Also, time to ask questions, clarifications…

5 ECTS credits correspond to 11 hours of work per week during the 13-week period (DTU rules). You are expected to continue working on studying the theory, solving the problems and course project during the afternoon or other time!

Asking questions

We are a very large group and need to work together and efficiently !

1. Use time at the end of every lecture to ask questions

2. <u>Do not sent questions by email</u>. Ask all questions online through the Discussions section in the online platform Learn, then other students can also benefit from the answers!

3. Meet Lukas and Marco in their office hours

Lukas Karkossa (PhD student)

Marco Saretta (PhD student)

Course learning outcomes

- Describe the structure of multi-carrier energy (electricity, heat, natural gas and hydrogen) systems and components at the interface between them.
- Explain the synergies between the energy sectors and the concepts of sector coordination.
- Describe the optimal energy flow problem for different energy carriers and the approaches to solve it.
- Formulate the optimal power flow problem for transmission and radial distribution systems on a computer.
- Formulate the optimal gas flow problem on a computer.
- Formulate the optimal heat flow problem on a computer.
- Explain the similarities between energy flow problems for different energy carriers, and the multi-energy flow problem.
- Interpret, analyze, and present numerical results.

Preparing to work with the problems

We are going to learn and use open modeling software and data science approaches to deal with energy grids including : Python, pandas, numpy, matlplotlib, networkX, Linopy, PyPSA

Lectures will focus on relevant theory and problems will be solved using open-source software.

To help everyone learn the models, introduction in the form of jupyter notebooks will be provided.

https://martavp.github.io/integrated-energy-grids/intro.html

You need to set up an environment as described here: https://martavp.github.io/integrated-energy-grids/intro-install.html

If you don't have previous experience with python, just start with the introduction to Python

https://martavp.github.io/integrated-energy-grids/intro-python.html

Evaluation

Written exam (4 hours, all aids) on May 26, 2025

Optional: up to 0.5 points (out of 10) for presenting the problems the day that your group is assigned

(see groups created based on last name, file “Groups_for_problems_presentations.pdf”)

Optional: up to 2 points (out of 10) for course projects (in groups of 4 students, you create the groups yourselves, if you have questions ask the TAs)

(optional) Course project

A step-by-step guide is provided but the objective is that you incorporated into the project all the learnings that you are getting throughout the lectures.

https://martavp.github.io/integrated-energy-grids/Problems/IEG_course_project.html

Then, write a short report (maximum length 10 pages) in groups of 4 students including your main findings.

A. Choose a different country/region and calculate the optimal capacities for renewable and non-renewable generators. You can add as many technologies as you want. Remember to provide a reference for the cost assumptions. Plot the dispatch time series for a week in summer and winter. Plot the annual electricity mix. Use the duration curves or the capacity factor to investigate the contribution of different technologies.

B. Investigate how sensitive the optimum capacity mix is to the global CO_2 constraint. E.g., plot the generation mix as a function of the CO_2 constraint that you impose. Search for the CO_2 emissions in your country (today or in 1990) and refer to the emissions allowance to that historical data.

C. Investigate how sensitive your results are to the interannual variability of solar and wind generation. Plot the average capacity and variability obtained for every generator using different weather years.

D. Add some storage technology/ies and investigate how they behave and what their impact is on the optimal system configuration. Discuss what strategies is your system using to balance the renewable generation at different time scales (intraday, seasonal, etc.)

E. Select one target for decarbonization (i.e., one CO_2 allowance limit). What is the CO_2 price required to achieve that decarbonization level? Search for information on the existing CO_2 tax in your country (if any) and discuss your results.

(optional) Course project

F. Connect your country with, at least, two neighbouring countries. You can connect them using HVAC lines, HVDC links or gas pipelines. Use a linear representation of power flow or gas flow. You can assume that the generation capacities in the neighbouring countries are fixed or optimize the whole system. You can also include fixed interconnection capacities or optimize them with the generators' capacities. Discuss your results.

G. Connect the electricity sector with, at least, another sector(e.g. heating or transport), and co-optimize all the sectors. Discuss your results.

H. Finally, select one topic that is under discussion in your region. Design and implement some experiment to obtain relevant information regarding that topic. E.g. What are the consequences if Denmark decides not to install more onshore wind? Would it be more expensive if France decides to close its nuclear power plants? What will be the main impacts of the Viking link? How does gas scarcity impact the optimal system configuration?

Draft calendar

Week	Date	Lecture
1	Feb 5	Course presentation. Balancing renewable generation. Introduction to storage and transmission.
2	Feb 12	Review optimization Optimal dispatch in one node
3	Feb 19	Networks
4	Feb 26	Linearized Power Flow
5	Mar 5	Power flow
6	Mar 12	Gas networks and optimal gas flow
7	Mar 19	Heat networks and optimal heat flow
8	Mar 26	Join capacity and dispatch in a single node
9	Apr 2	Limiting CO2 emissions
10	Apr 9	Join capacity and dispatch optimization in a network.
	April 16	No lecture (Easter)
11	Apr 23	Multi-carrier energy systems (heating and land transport)
12	Apr 30	Multi-carrier energy systems (industry, aviation, shipping)
13	May 7	Advanced topics / Invited lecture

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