



**UNIVERSITY
OF OSLO**

Assignment 2 - Mathematical formulation and GAMS implementation of a future energy system

TEK5410 – Energy Markets and Regulation -
Electricity System Modelling and Analysis

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September 10, 2025

1 The Future Energy System of the Free Republic of Liberland

1.1 Background information

Liberland, also known as the Free Republic of Liberland, is a micronation in Southeast Europe claiming an uninhabited parcel of disputed land on the western bank of the Danube, between Croatia and Serbia (locally known as Gornja Siga). The land was proclaimed on 13 April 2015 by the Czech right-libertarian politician and activist Vít Jedlička. Even if Liberland has not been recognised by any nation, and both Croatia and Serbia have dismissed its claims as foolish, Jedlička has reached out to you for help with designing its potential future energy system¹.



Figure 1.1: Picture showing the area for Liberland as well as neighbouring countries

As energy experts, you are tasked with finding the best combination of different electricity generating technologies, while meeting the requirements set up by this "state".

As of right now, the population and infrastructure of Liberland is limited, but with over 600,000 applications for citizenship, this may very well change in the near future.

¹The facts and number in this assignment are made up.

According to Liberland’s own projections, the combination of residential and commercial activities, as well as larger events, such as the annual crypto festival, *Floating man*, electricity demand is expected to be at least 4,000 GWh annually,

When it comes to electricity generation, only certain technologies are relevant. These are onshore wind power plants, natural gas fired power plants, small modular nuclear reactors and run-of-river hydro power from the Danube. Despite claiming to be a libertarian state, the authorities of Liberland have set down some basic requirements for its future energy system.

As a way to maintain decent living standards, both locally and long-term globally, it is important to limit the amount of greenhouse gases emitted from the electricity sector in Liberland. Emitting at most 100,000 tCO_{2e} annually is expected to meet those requirements.

Furthermore, concerns around the visual aesthetics of wind power and limited area available have led to a temporary upper limit of 1,200 GWh of electricity generated from onshore wind power plants. Surprisingly, official reports claim that the wind speeds and water flows in Liberland are the same at all time and does not vary whatsoever, completely removing any issues of intermittency from these renewable energy sources.

While small modular nuclear reactors are still considered as an uncertain technology, with relatively high associated levelised cost of electricity, the authorities of Liberland do not mind. As such, they ask that you include at least 200 GWh of SMR produced electricity.

Technology	LCOE [\$/MWh]	Emission factor [tCO _{2e} / MWh]
Onshore wind	150	0
Natural gas	100	0.2
SMR (Nuclear)	400	0
Hydro power	160	0

Table 1.1: Cost and emission data for electricity generation in Liberland

Liberland have previously acquired information on levelised cost of electricity for the relevant technologies, which they have kindly summarised in table 1.1.

1.2 Tasks

- Filter out the relevant information from the text above and identify the components of the optimisation problem (e.g. objective, decision-variables and constraints)
- Identifying the relevant components of the optimisation problem and structure the problem mathematically
- Once you think that you have outlined and structured the mathematical problem, go on and implement it GAMS.

At the beginning of lecture 3 (24 September), we will randomly select two students out of those who did the assignment to present for the class, one for the mathematical formulation and equations and one for the GAMS implementation.

You are free to collaborate and help each other with the assignment, but remember that you need to be able to explain what you did and why if you are picked to present at the next lecture.

If you get stuck, ask questions in the discussion forum on canvas, and we can point you in the right direction / give hints. Otherwise, the office hour on 17 September is a good opportunity.