

# Lecture 2: Optimization

DTU Course 46770: Integrated Energy Grids

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**Problem 2.1.** Given the following optimization problem,

$$\begin{aligned} \max_{x,y} \quad & 2x + 5y \\ \text{s.t.} \quad & x \geq 1, \\ & -x + y \geq -3, \\ & 2x + y \leq 14, \\ & -\frac{1}{2}x + y \geq \frac{3}{2}. \end{aligned}$$

- Solve the optimization problem graphically (pen and paper or on your laptop). Note that it is a maximization problem, whereas we will mostly work with minimizations. Reformulate as a minimization problem.
- Return to the original formulation. Indicate which constraints are binding and calculate the values of the Lagrange multipliers.
- In the above set-up, we have a unique solution to our maximization problem (existence and uniqueness). Adapt the exercise such that this is no longer the case.

**Problem 2.2.** Consider the following economic dispatch problem:

- we have three generators: solar, wind and gas
  - solar and wind have no marginal costs, and gas has fuel costs of 60 EUR/MWh.
  - we need to cover demand of 13.2 MWh
  - the installed capacities are 15 MW, 20 MW and 20 MW for wind, solar, and gas, respectively
  - assume the capacity factor for solar is 0.17 and for wind 0.33.
- Use linopy to define and solve the LP and find the optimal solution as well as reading out the Lagrange multipliers as defined in the lecture.
  - Open `problem2b.csv`, and use the values as inputs for capacity factors as well as demand in the dispatch problem. Solve the LP with linopy.
  - Open `problem2c.csv`, and use the values as inputs for capacity factors as well as demand in the dispatch problem. Solve the LP with linopy.
  - Compare the share of renewable generation, the dual variables, and the objective from a)-c) [average, median, min, max] and interpret the differences. Compute the curtailment from renewables.

- e) Plot the supply and demand curves for the different resources in c). Also consider **demand - renewable generation** (“net load”). Could transmission or storage be useful for this system? Why or why not?

**Problem 2.3.** We assume the system from Problem 2.2.

- a) Another system that is connected to ours — assuming copper-plate — decides dispatch just before we do and can export utility solar. The results from that dispatch optimization are saved in **problem3a.csv**. Create a time series of available imports and their price.
- b) Solve the updated problem with the available imports. Think of the imports as a generator with variable, marginal prices corresponding to the dual variables.