Optimal Dispatch Schedule in District Heating Network

Ray Pörn, Mats Borg & Johan Westö

15.5.2025

NOVIA
UNIVERSITY OF APPLIED SCIENCES

Seinäjoen Energia
Elämäsi hetkissä

MINISTRY OF
EDUCATION AND CULTURE

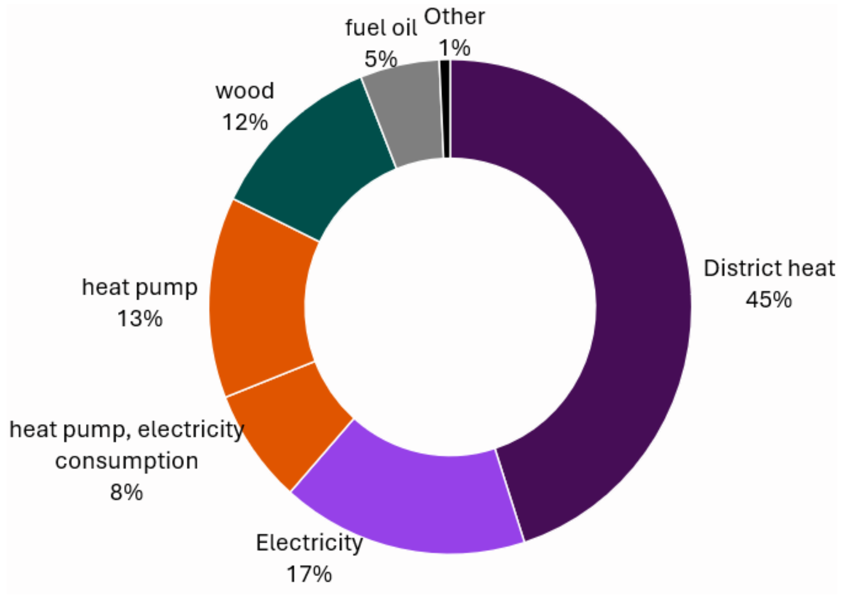
EPV

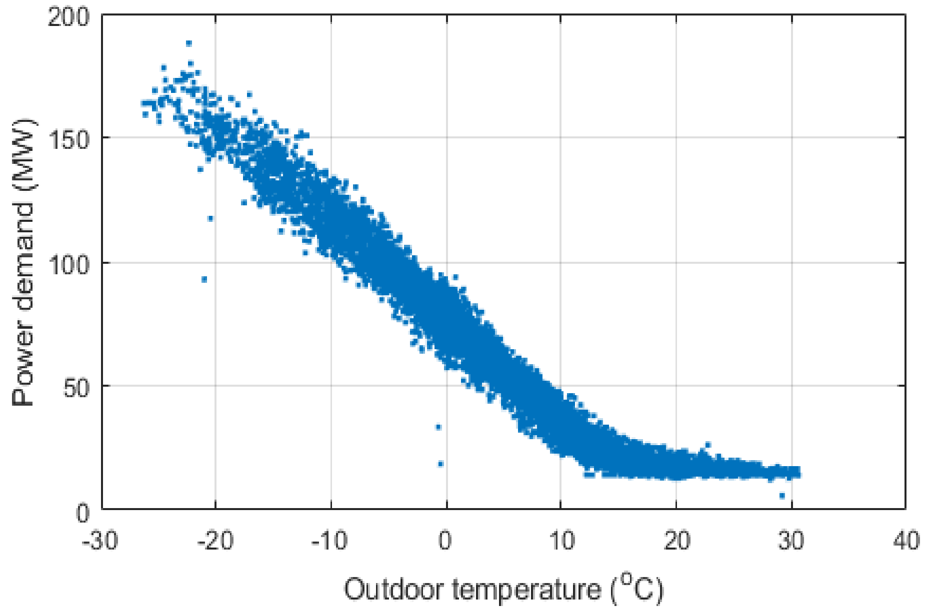
Presentation outline

- Background and objective
- Introduction and problem description
- Optimization model for dispatch scheduling
- Hypothetical use case: Optimal dispatch scheduling
- Hypothetical use case: Investment simulations
- Summary

Background and objective

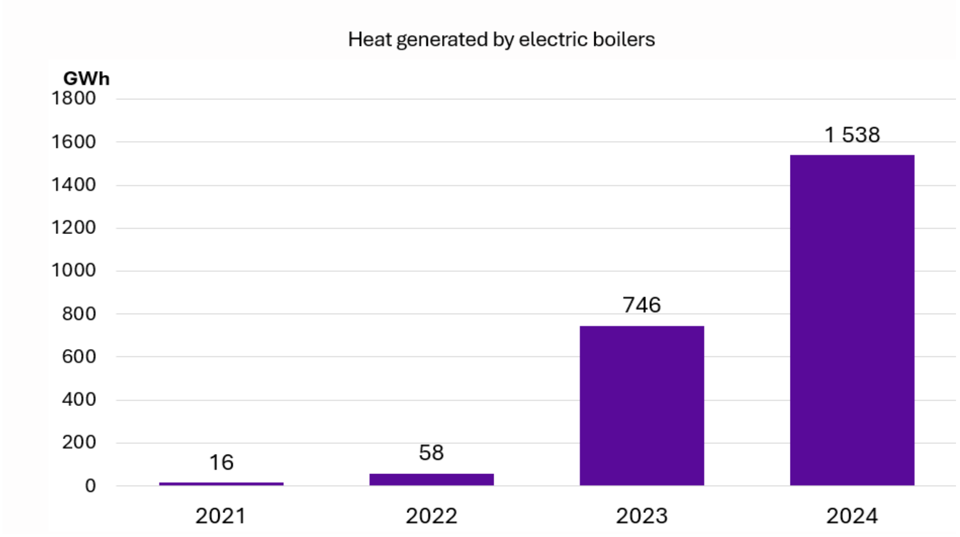
- This research has been conducted within the FESIO project during years 2022-2024.
- The project partners have been Seinäjoki Energia (SEN) and Etelä-Pohjanmaa Voima (EPV).
- **Research objective: Develop an optimization model for the dispatch scheduling of the boilers and simulate potential savings when introducing changes in the network settings (electric boiler, heat pumps, heat storage, data centers, …).**
- Almost 50% of buildings in Finland use district heating (Finnish Energy, 2022).
- Heat demand in district heating is primary driven by outdoor temperature.

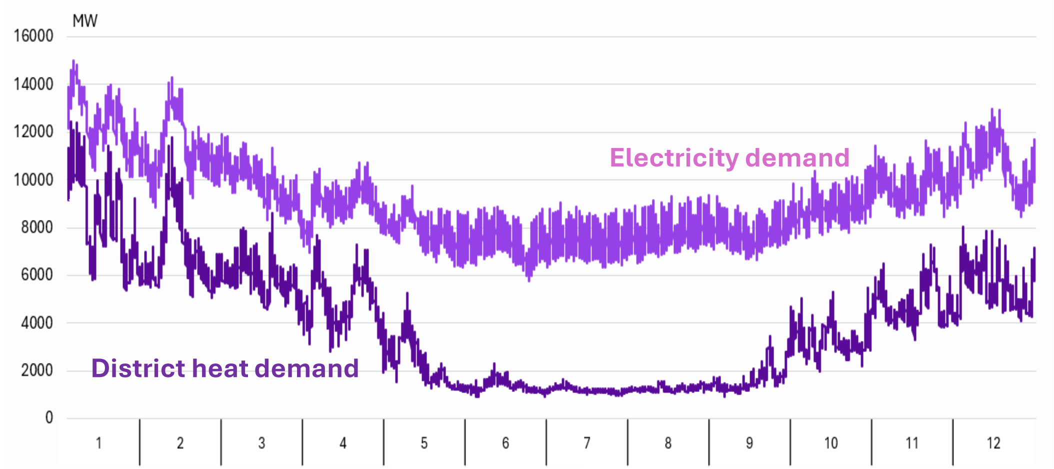




Introduction

- Fuels in district heating networks are changing due to a combination of **environmental**, **economic** and **technological** factors.
- *Environmental*: District heating must reduce CO_2 emissions, especially in the Nordic countries.
- *Economic*: Global events (e.g. energy crises, wars, pandemics) lead to price peaks and high volatility in the price of fuels such as oil and natural gas.
- *Technological:* Introduction of low-temperature networks, electrical boilers, waste heat recovery with heat pumps and heat storage.
- The use of large electrical boilers has recently “exploded” in Finland (Finnish Energy, 2024). Electrical boilers reduce the use of fuel-based boilers when electricity price is low.
- Electricity and district heat demand have become more correlated (Finnish Energy, 2024).





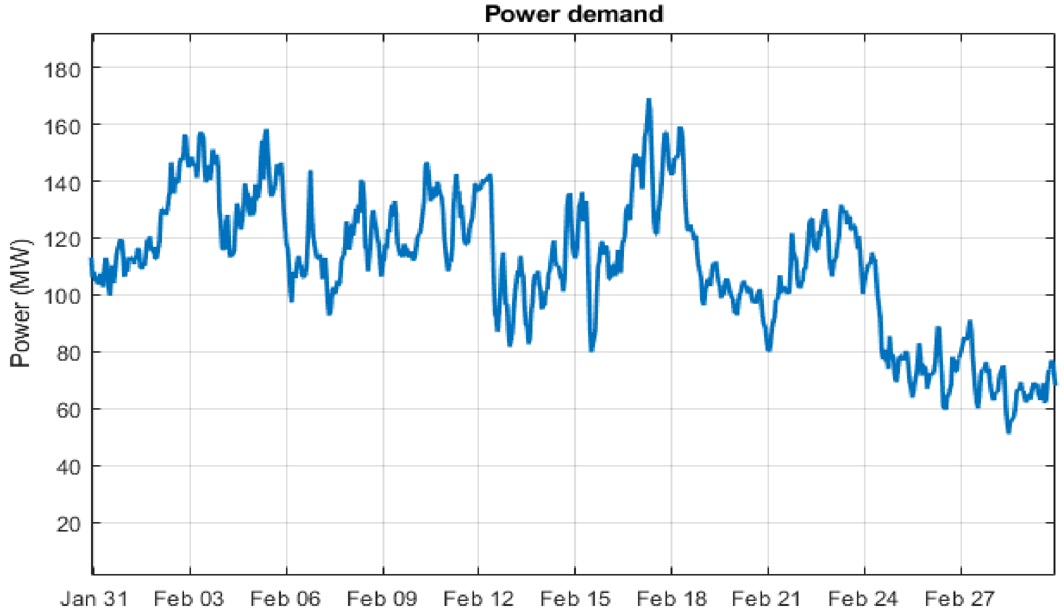
Introduction

Challenges with district heating:

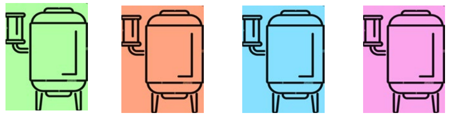
- Variable heat power demand that must be met.
- Scheduling of multiple heat production units (boilers, heat pumps, heat storage, …)

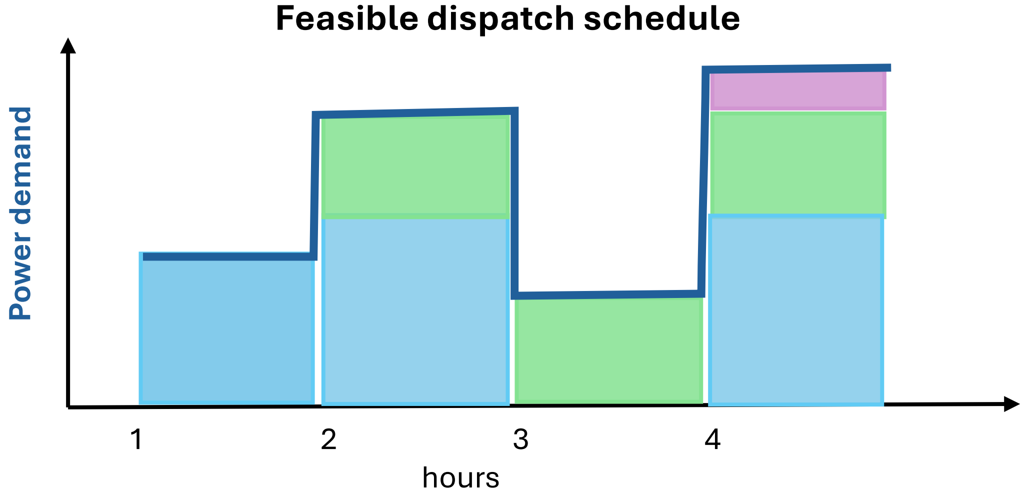
Motivation for dispatch optimization:

- Need for cost-effective operation.
- Provides a lower bound for the total cost.
- Can be extended to simulate savings for changes in the set of heat production units.
- Provides support for investment decisions.



Boilers





Optimal dispatch scheduling

The optimal dispatch scheduling problem can be formulated as a **mixed linear optimization problem**.

Parameters

- Heat power demand
- Production costs and startup/shutdown costs of boilers
- Capacities and bounds of boilers
- Heat storage size and specifications

Variables

- Power output for each boiler
- Logical variables to model boiler status on/off
- Logical variables to model startup/shutdown costs
- State-of-charge of heat storage (energy/temperature level)

Objective

- Minimize total cost (production + startup/shutdown cost)

Constraints

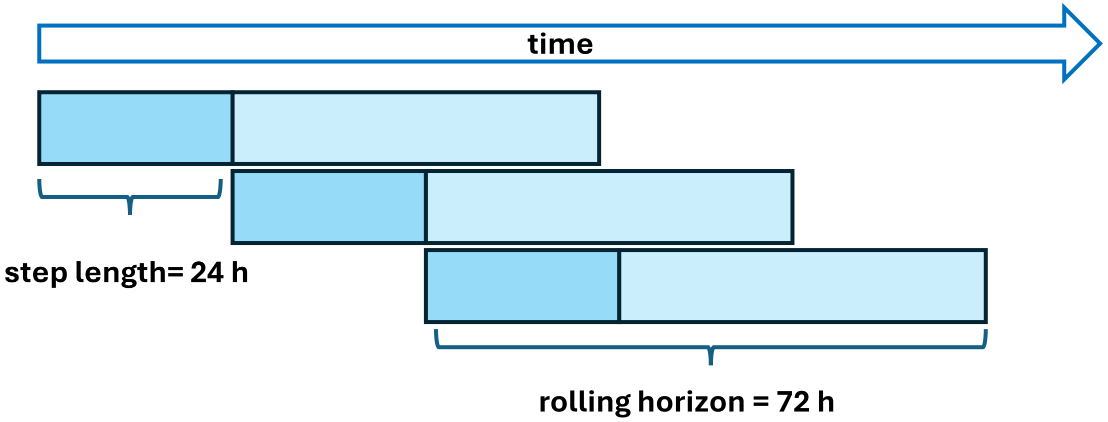
- Power demand constraint
- Power bounds for boilers
- Linearization constraints for boiler logic
- Energy balance of heat storage

Simple heat storage model:

- Modeled as a battery.
- Empty: 50 ^{o}C, Full: 95 ^{o}C (1000 m3 <-> 52 MWh)
- Charging/discharging can be done at a power equivalent to the electric boiler capacity.
- State-of-charge of heat storage **not fixed** at the end of rolling horizon.

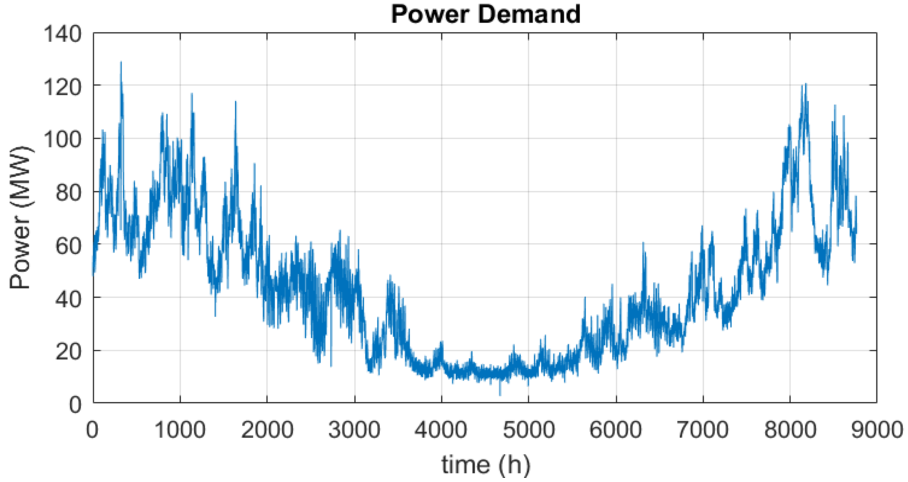
Optimization using <u>rolling horizon principle</u>:

- The yearly optimized cost is computed using a rolling horizon strategy using a forward window length of 3 days (72 hours).
- The step length is set to 24 hours.

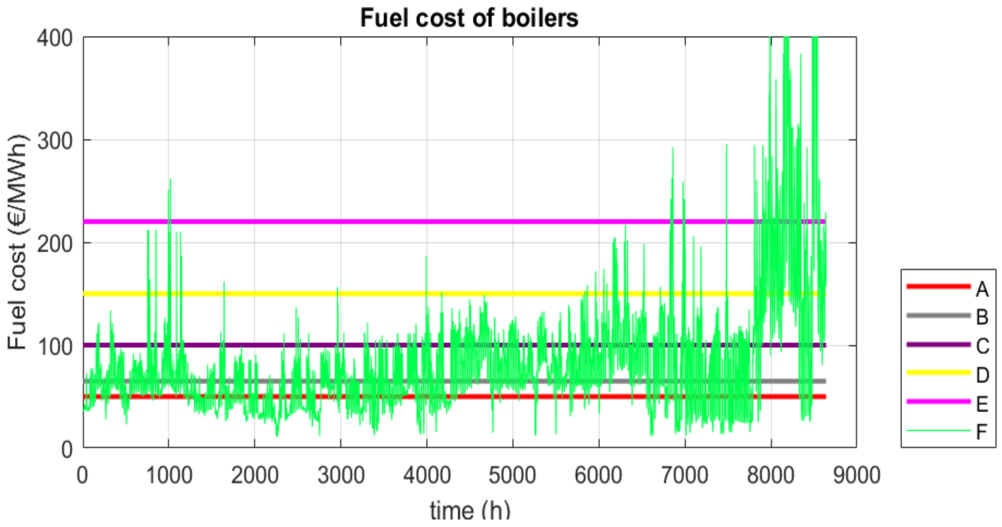


Case study: Hypothetical district heating network

- Example year: 2021 (hypothetical heat power demand data and real spot price data)
- Hourly heat power demand in plot.
- Current boiler setting in table (capacities, bounds and costs).
- Lower bounds on operating level for boilers A-C.
- Startup and shutdown costs are included.
- Six boilers in the network. Boiler F is a small electric boiler that runs with spot price + 12 €/MWh. Fuel costs illustrated in plot.
- Heat storage included in the simulations.



Boiler	Pmax	Pmin	Cost (€/MWh)	Startup (€)	Shutdown (€)
A	50	15	50	10000	2500
B	38	8	65	6500	2000
C	20	3	100	3000	1000
D	12	0	150	500	0
E	10	0	220	300	0
F	5	0	spot+12	0	0

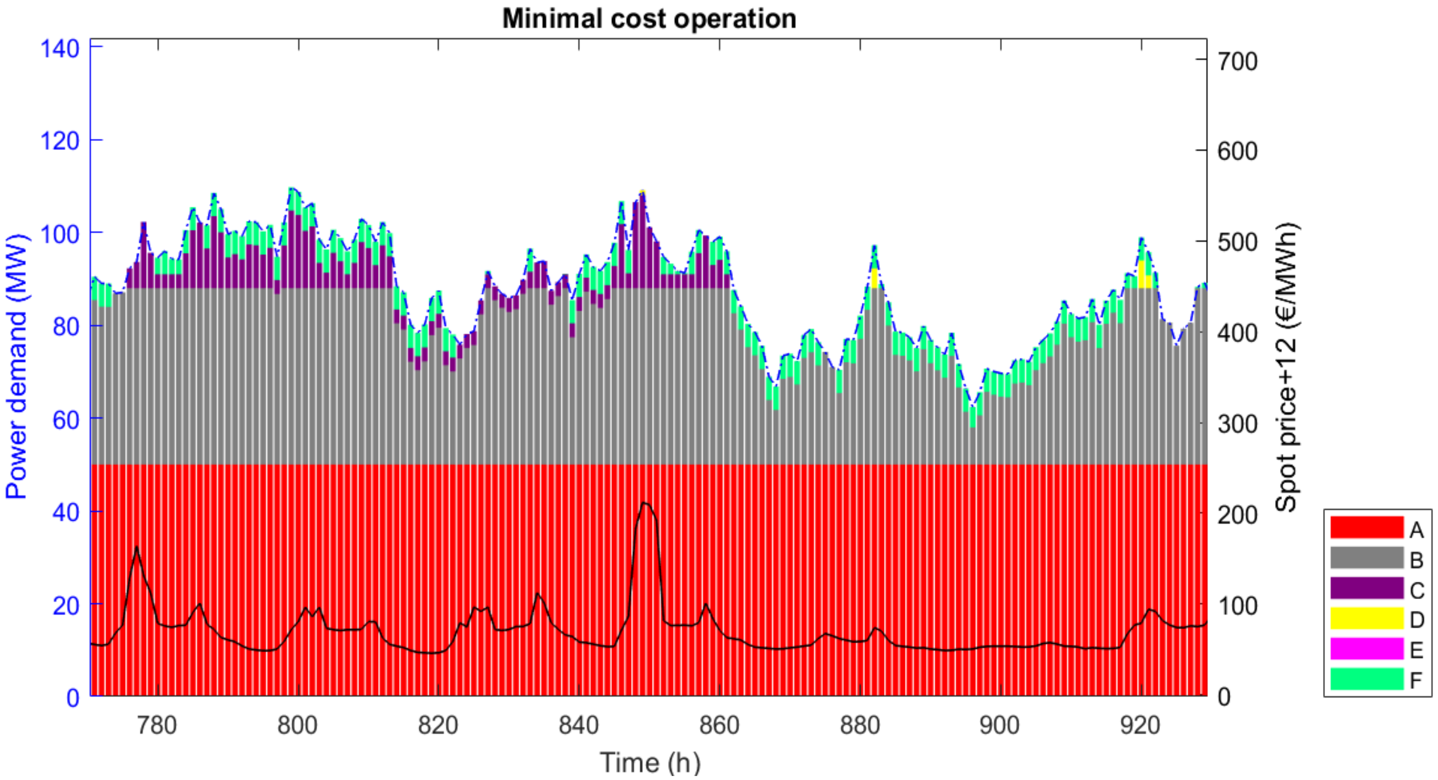


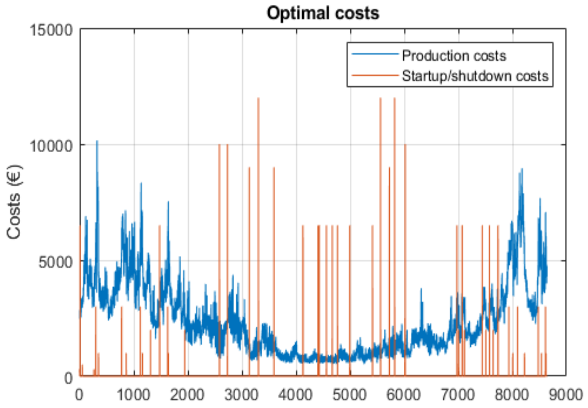
Current configuration

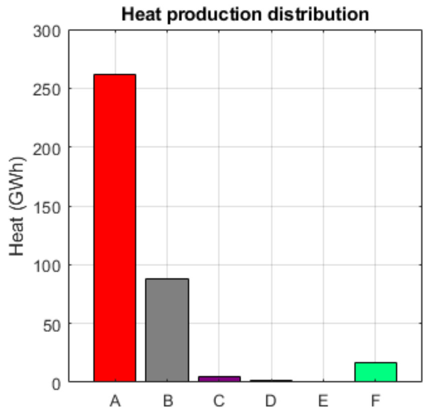
Boiler	Pmax	Pmin	Cost (€/MWh)	Startup (€)	Shutdown (€)
A	50	15	50	10000	2500
B	38	8	65	6500	2000
C	20	3	100	3000	1000
D	12	0	150	500	0
E	10	0	220	300	0
F	5	0	spot+12	0	0

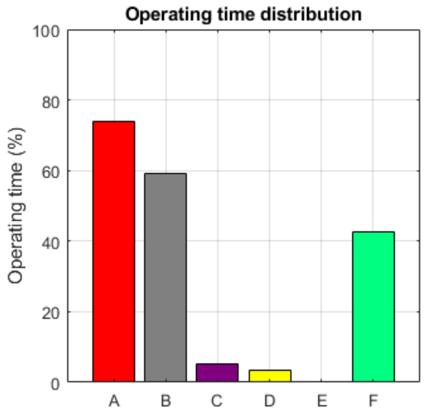
- Yearly heat demand: 381 GWh
- Total optimized yearly cost (2021): 20,5 M€.
- Average price of heat: 53,70 €/MWh.

- Simulation study: The company is interested in potential savings when including a larger electric boiler and also a small-medium sized heat storage.









Simulation principle and example

- Size of electrical boiler (MW):

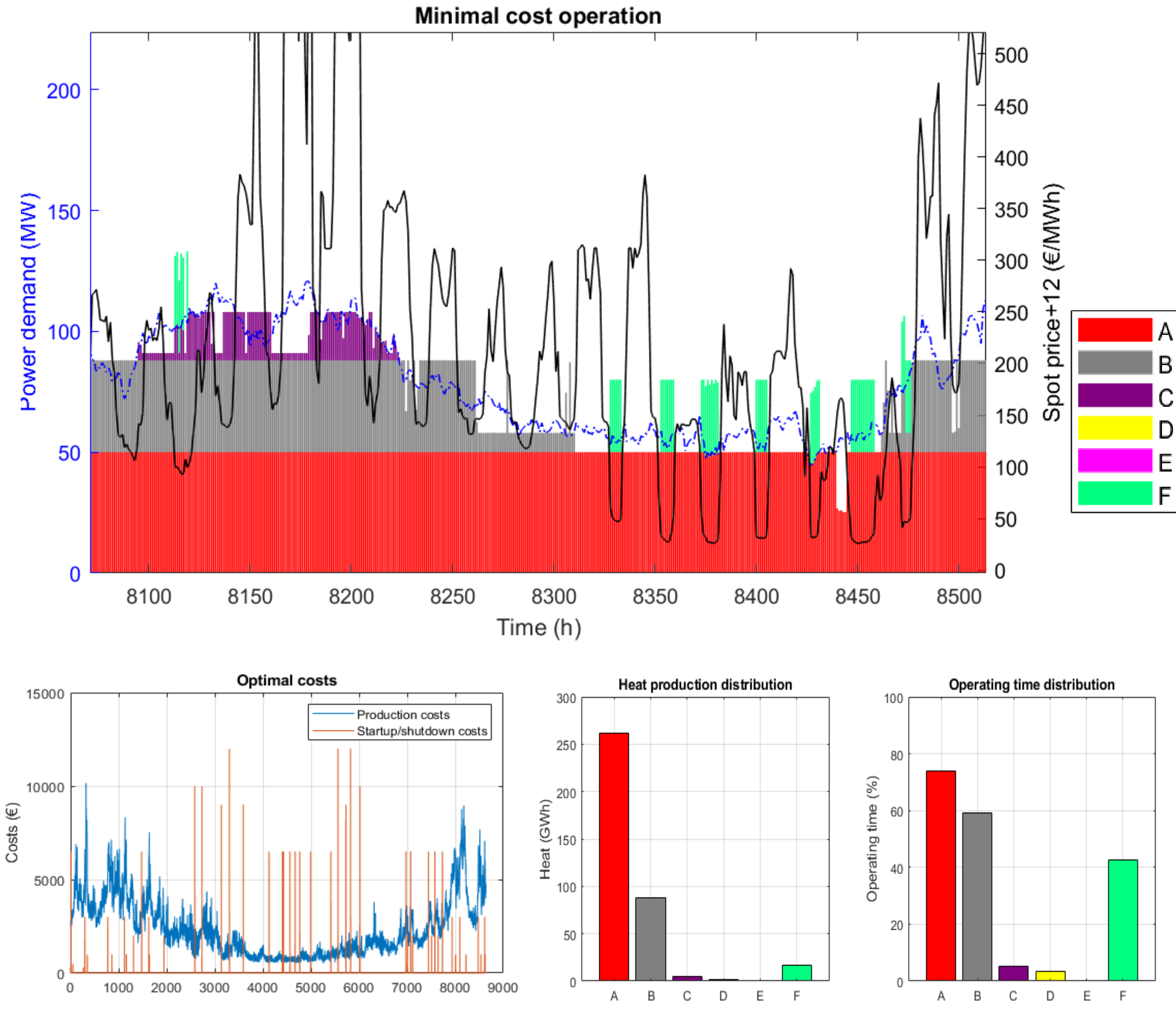
  5, 10, 15, …, 50 MW

- Size of heat storage (m3):

  1000, 2000, 4000, 8000, 16000

- For each combination of electric boiler and heat storage size we optimize the dispatch over the year 2021. The optimization is done by solving approximately 360 optimization problems using the rolling horizon strategy.

- **Example: 30 MW, 8000 m3 →**



Simulation results

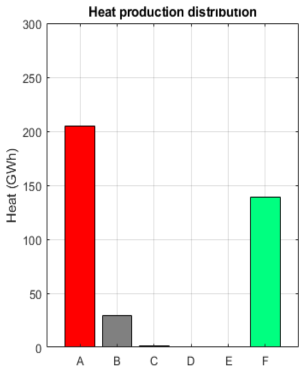
- The company is interested in potential savings when including a larger electric boiler and also a small-medium sized heat storage.
- Current situation:

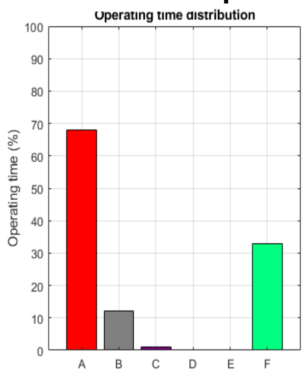
Some insights:

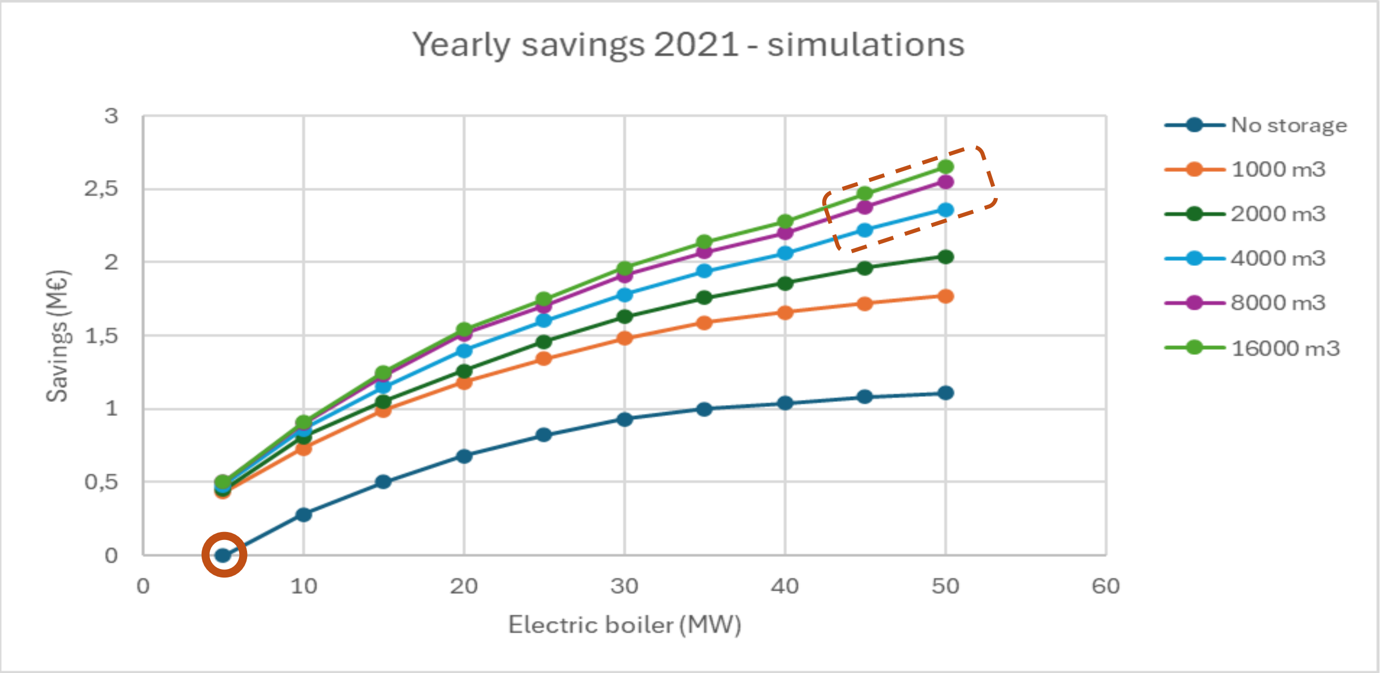
- A heat storage is a good investment, especially a small one.
- It is always beneficial with a larger electric boiler, but the benefit of larger heat storage flattens out.
- With 5 MW electric boiler it is enough to have a 1000 m3 heat storage.
- Equal savings for 1000 m3 heat storage and 10 MW of additional electric boiler capacity.
- Trend break! Why?

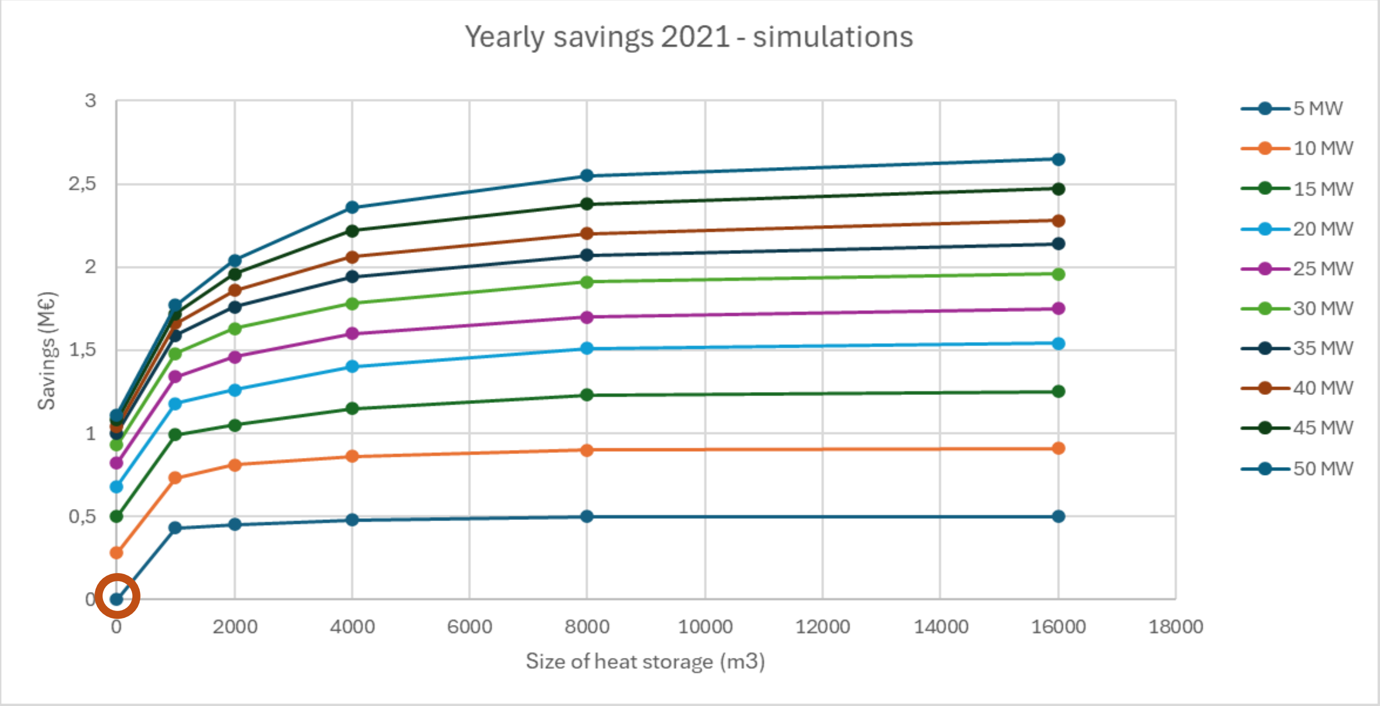
Large electric boiler + heat storage replace heat production (50 GWh) and running hours from boiler A.

50 MW, 16000 m3









Summary

1. We have developed an optimization-based framework for optimal dispatch scheduling in district heating.
2. The framework can be used for estimating the lower bound for the total heat production cost in a district heating network.
3. The framework is adaptable to simulate changes in the set of boilers, inclusion of heat pumps and heat storage.
4. It can be used as a tool for supporting investment decisions.

Thank you!