

# Thermal Storage

## Two business case

Christian Fuglsang, Energy-Flexibility Consultant  
[christian@fuglsang.dk](mailto:christian@fuglsang.dk)



# About me

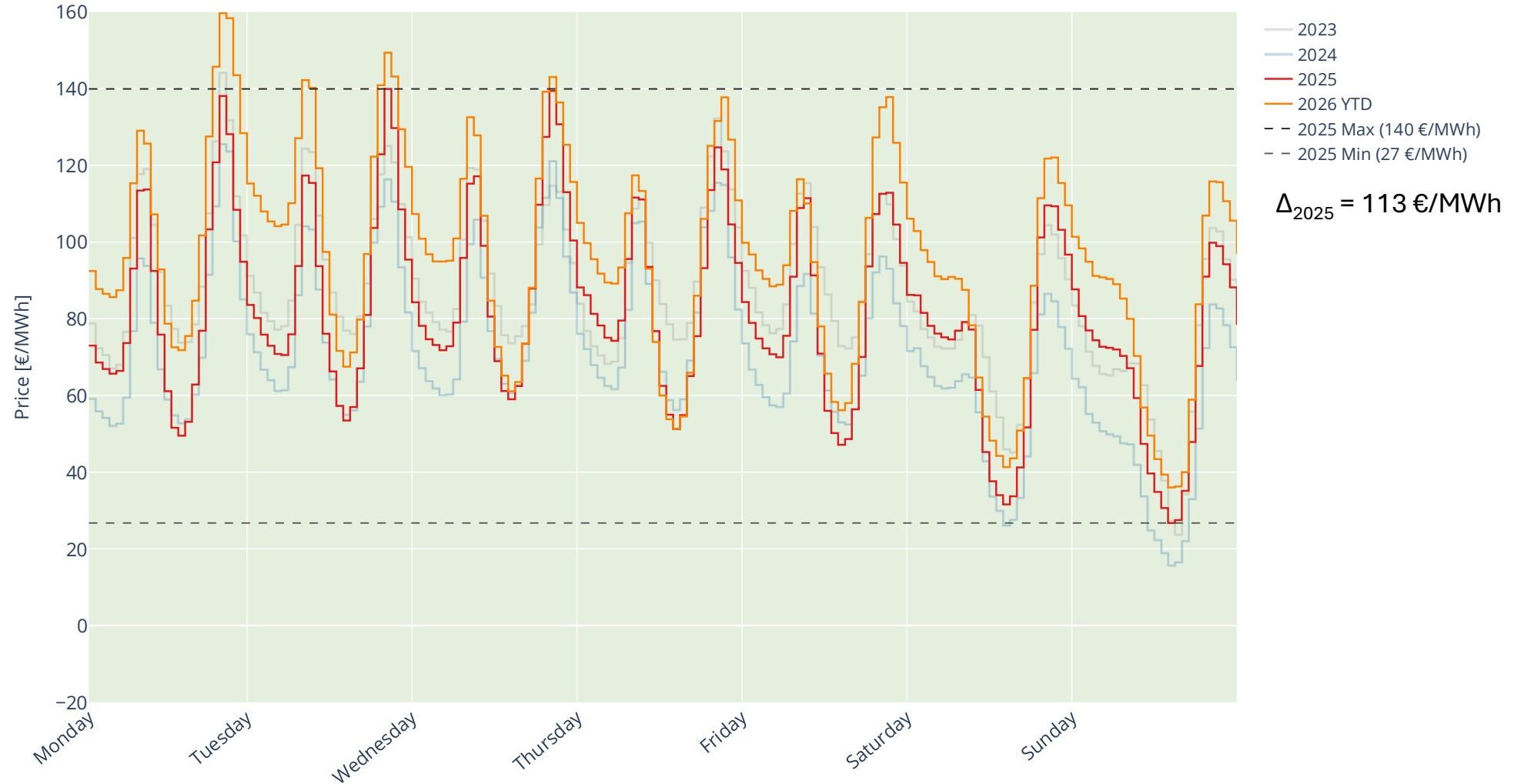
Christian Bülow Fuglsang

- 2019–2024: M.Sc. Engineering / Technical University of Denmark (DTU)
  - Thermodynamics, energy trading and linear programming/optimization
- Master's in operational optimization of complex energy systems in volatile energy markets
  - Winner of DTU Green Challenge 2024
  - Top 3 finalist for "Best DTU Operations Management Thesis"
- Founder of Fuglsang Green Engineering ApS
  - Consultancy with new thermal system designed with flexibility services
  - Grid integration and automatic energy trading for big industrial consumers and districts heating companies. (204MW<sub>th</sub>)



# Why is flexibility important?

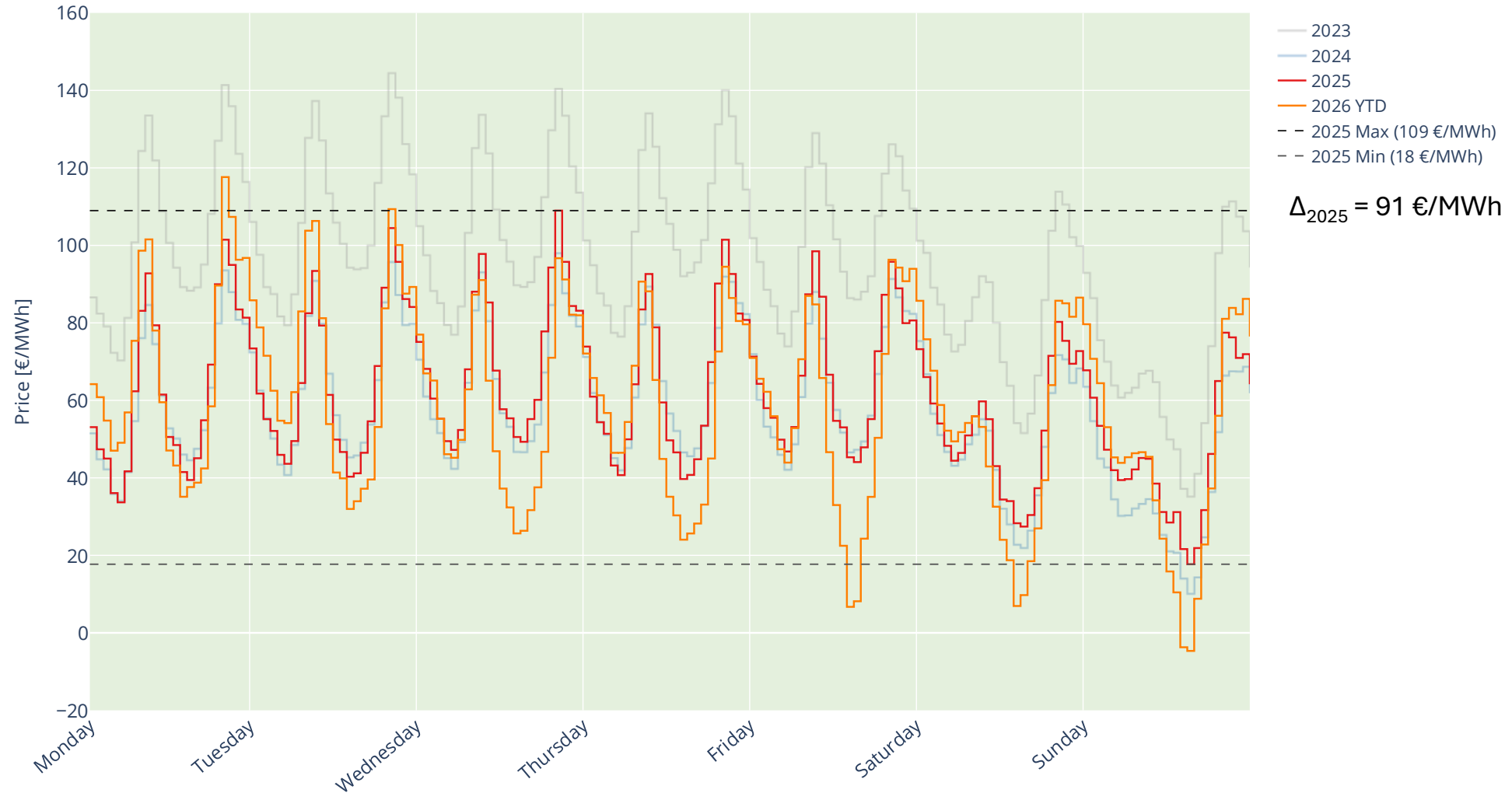
Average hourly electricity price by weekday - Denmark





# Why is flexibility important?

Average hourly electricity price by weekday - France

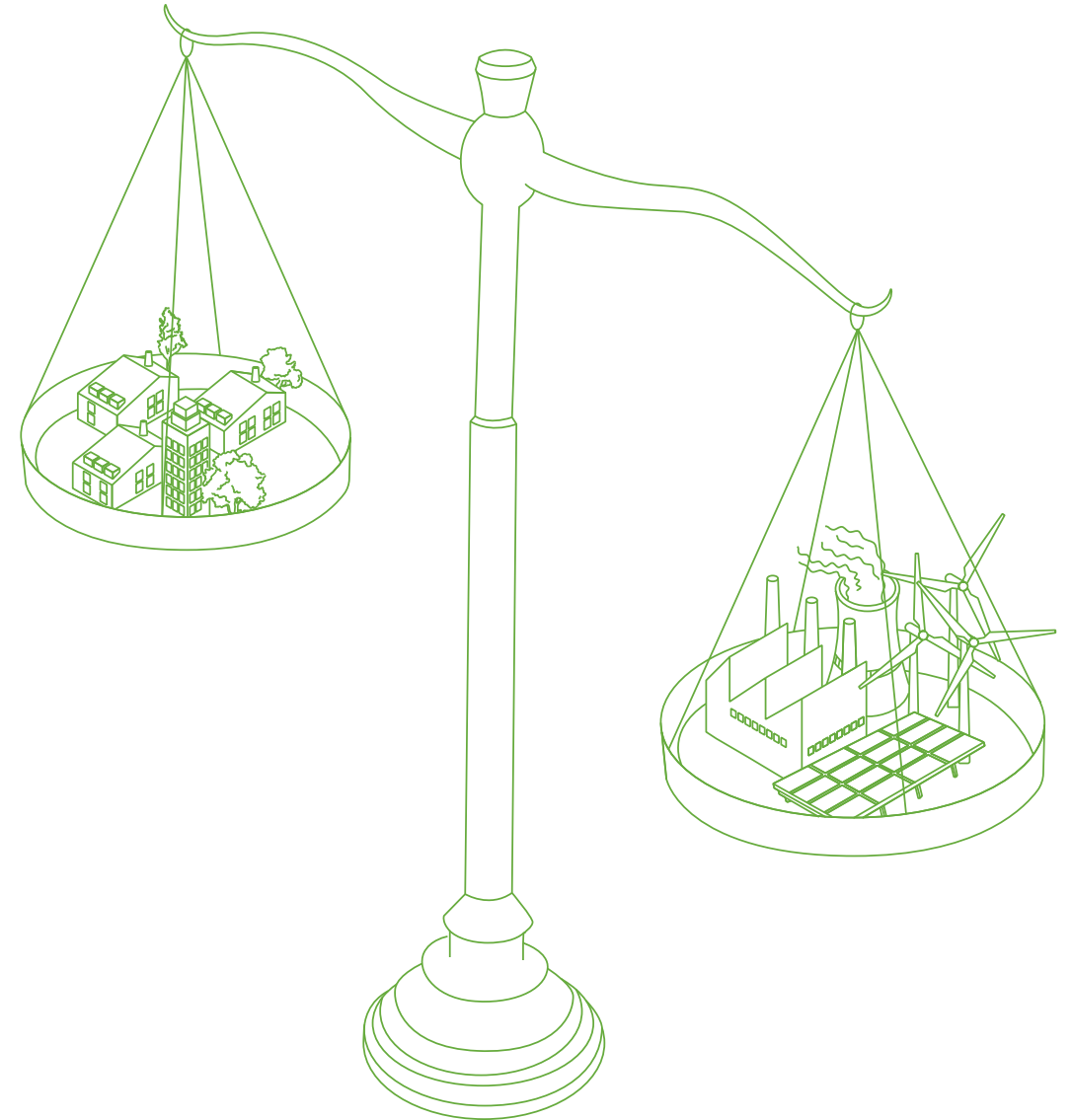




# Types of flexibility

The task of balancing the grid

- Day-ahead (Over the week)
- Intraday (In the day)
- Ancillary services (in the minute)

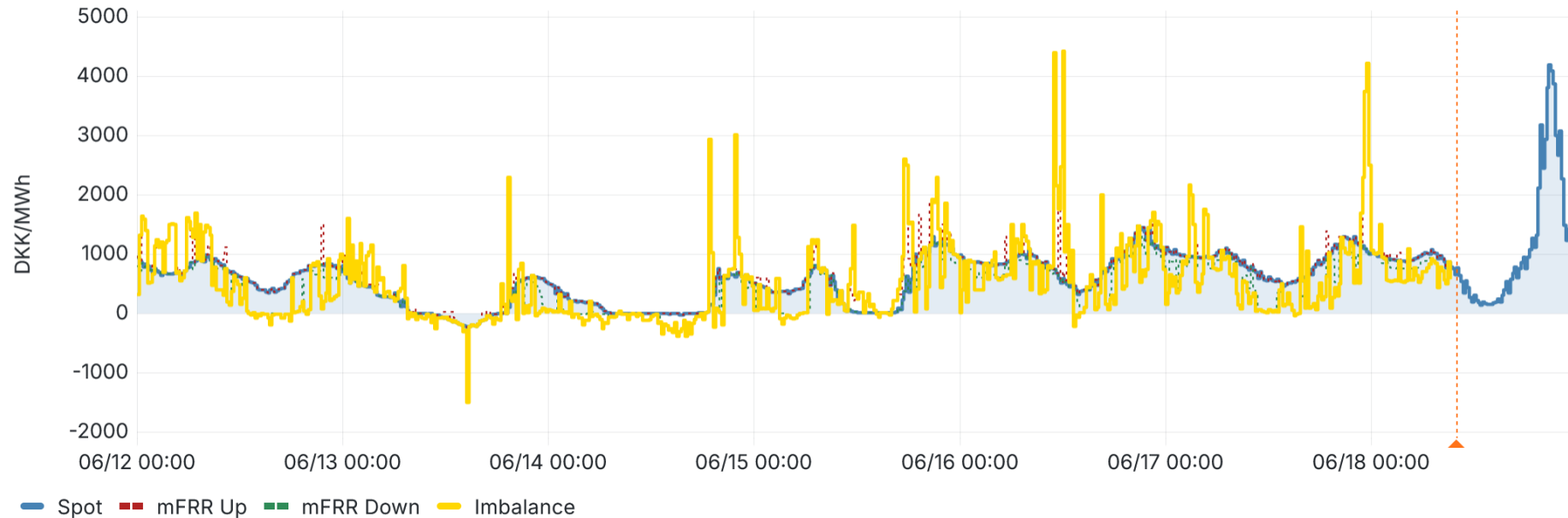




# Types of flexibility

The task of balancing the grid

Prices (DKK/MWh) — DK1

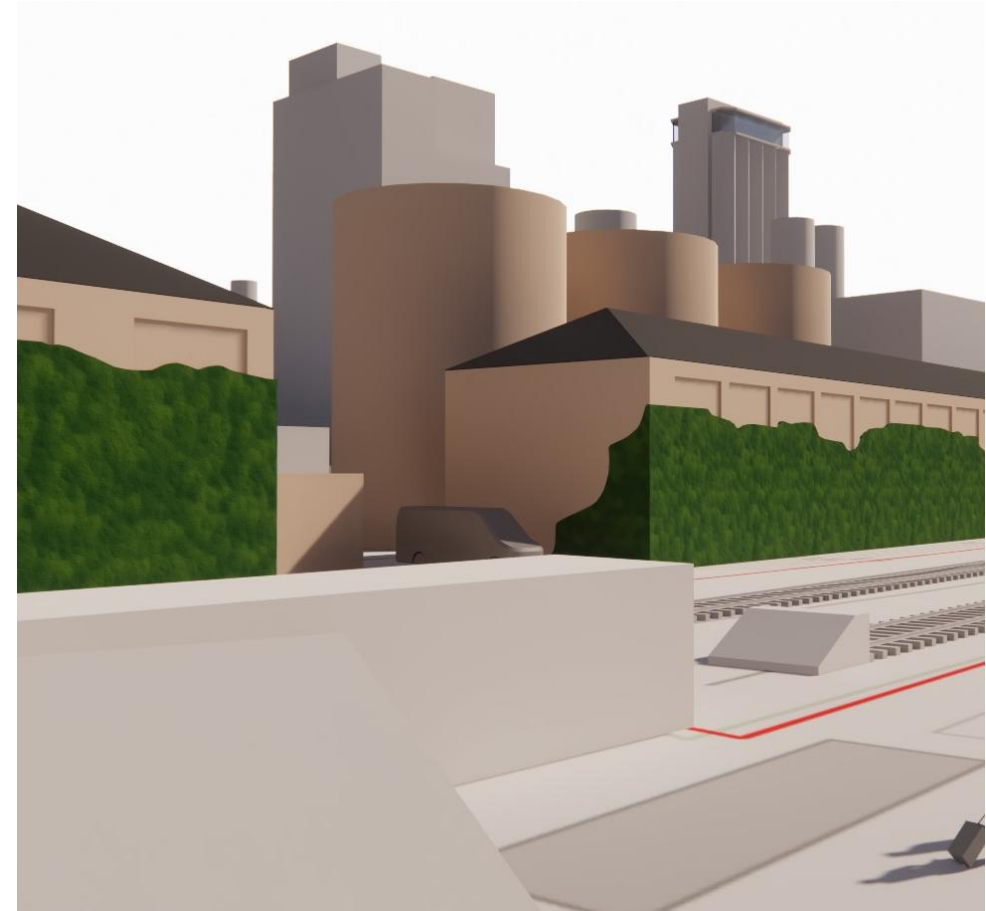




# A new fully electric heating plant for industry

Designed for high internal heat recovery and full flexibility with up to 5 days storage

- 94.000MWh/anno
- 2x 3,000 m<sup>3</sup> Accumulation tanks
- 15 MW Electric boiler
- 2.4 MW HTHP (95 °C)
  - Isobutane (R600a)
- Waste heat recovery
  - Drying process
  - Cooling process etc.
- 5 temperatures levels in the system
- Build to be highly flexible
- High surplus capacity



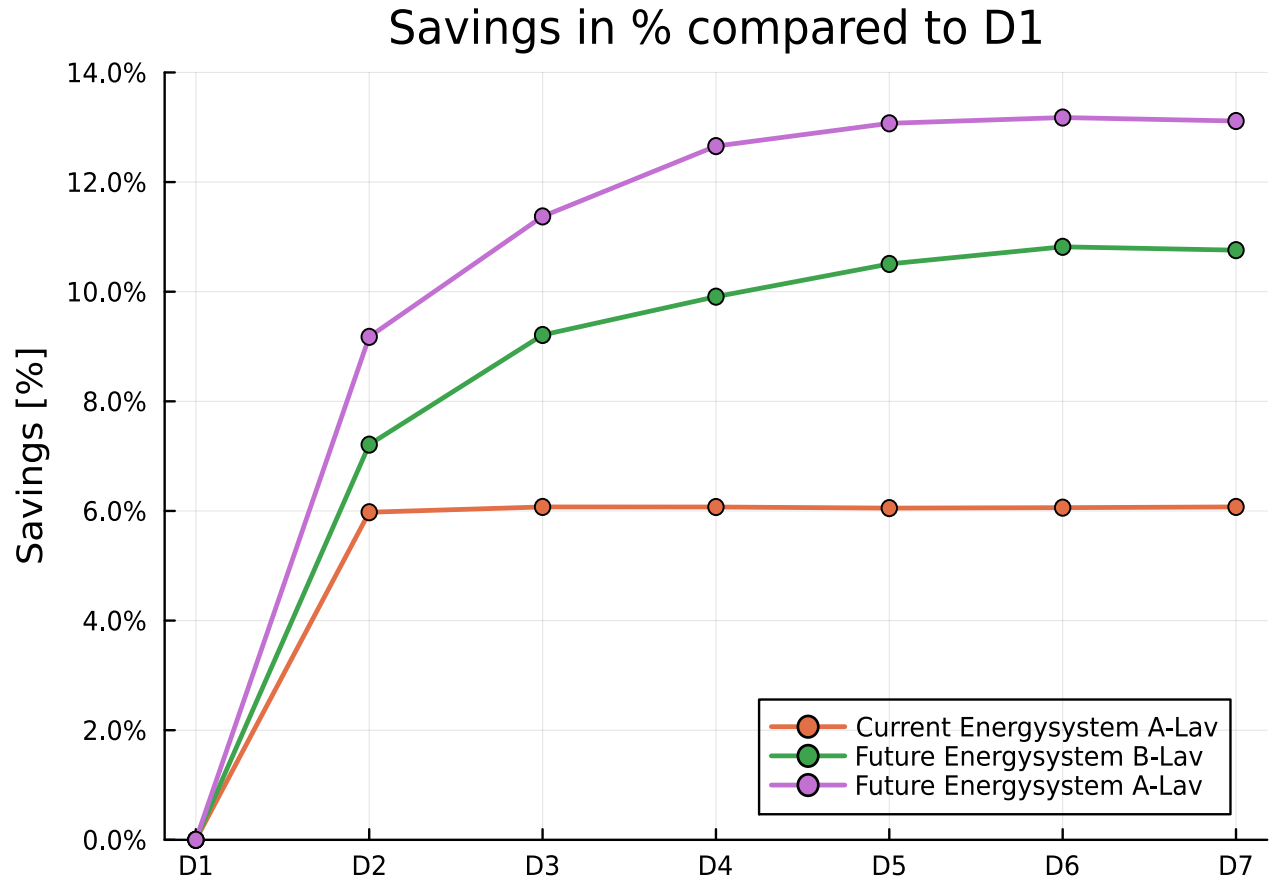




# Savings in just Day-ahead

Data from master thesis 2024 (Without ancillary services)

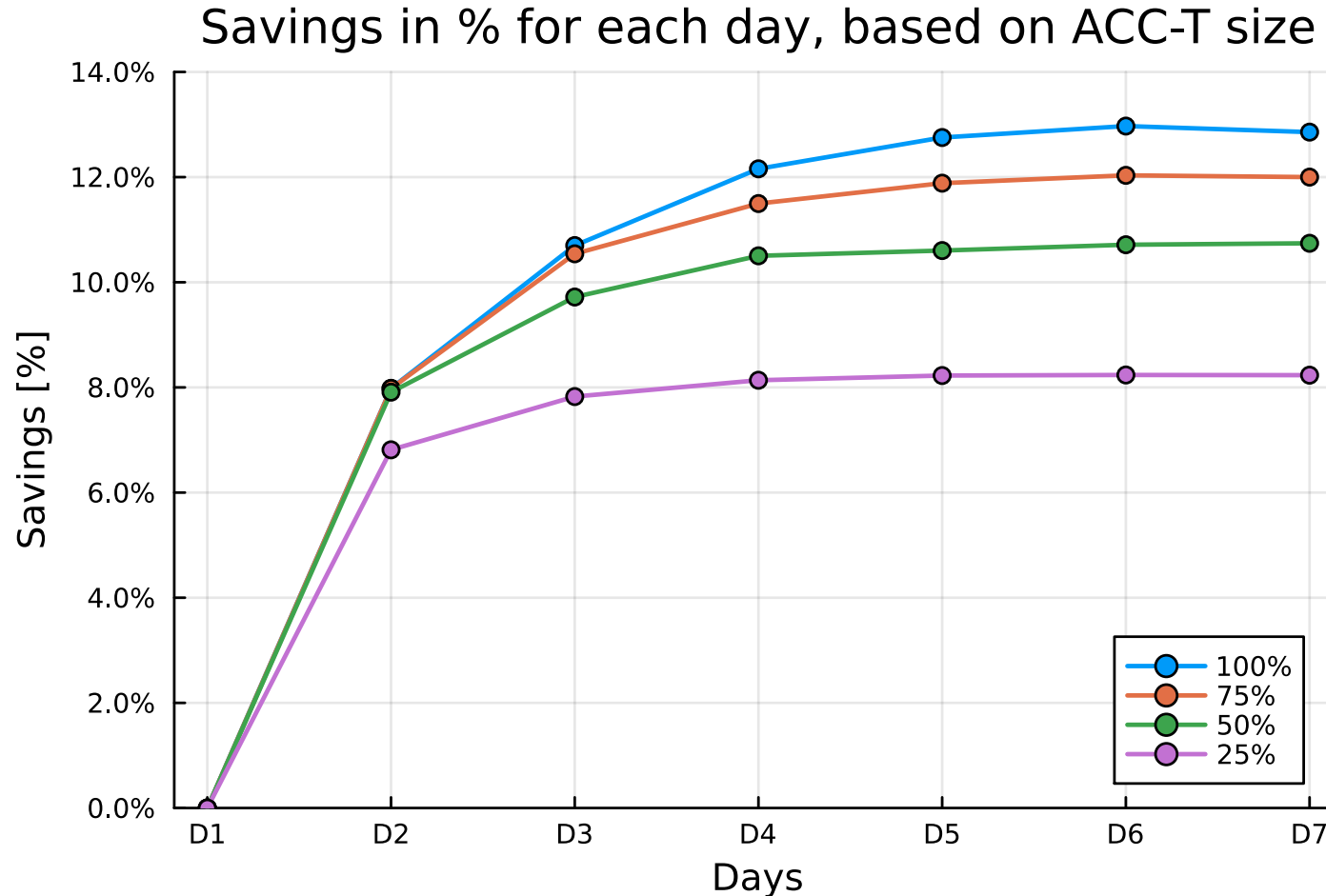
- 7-day arbitrage horizon heating cost down 13%
  - Current system from 1998 low flexibility 400m<sup>3</sup>
- **Full electrification cuts heating costs by 50%**  
(Not shown here)





# Lower savings without thermal storage

The longer the planning horizon, the bigger the thermal storage tank needs to be!



100% = 2x 3,000 m<sup>3</sup>



# The economic potential of ancillary services

Real data from May 2026

- Other Industrial customer - no Ancillary services utilized before
- Only 1 of 5 assets could deliver flexibility.
- Heating cost dropped with new optimization
  - Before 31 €/MWh in Jan-April
  - After 16 €/MWh in May

→ **Heat costs cut by 51% in May 2026.**

I expect more reduction on the new energy system with high flexibility and designed to run on Ancillary services!



# Is this a "un feu de paille"?

A short-lived success?

- Many wonder if high income from Ancillary services is short-lived.
- More renewables → more unstable grid
- Less fossil baseload → more unstable grid
- Private consumers don't flex.
- District heating and industry can flex, and with high volumes.

**Flexibility will always be an advantage!**

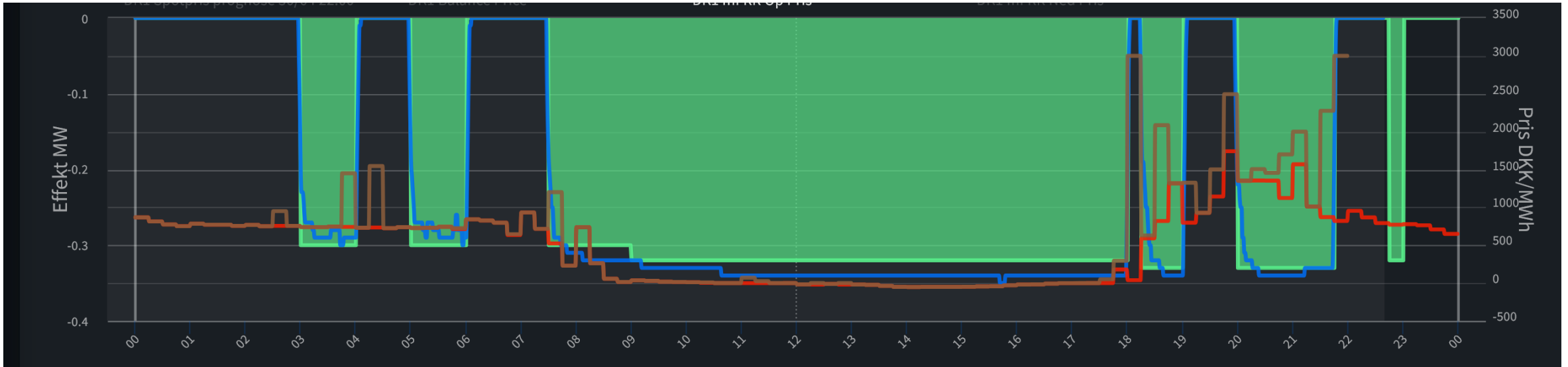
It's more about bidding something, then doing nothing.  
And knowing what the bid price should be



# What to bid? Heat pump example

Try every market has opportunity, if prices are high, the irrational is profitable.

Automatic handling is necessary for complex heat systems.



Market	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	00			
Day-ahead	0,3 MW 50,0 DKK	0,3 MW 50,0 DKK	0,3 MW 50,0 DKK	0,3 MW 50,0 DKK	0,3 MW 50,0 DKK	0,3 MW 50,0 DKK	0,3 MW 50,0 DKK	0,3 MW 50,0 DKK	0,31 MW 50,0 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK		
mFRR CM	0,3 MW 45,0 DKK	0,3 MW 45,0 DKK	0,3 MW 45,0 DKK	0,3 MW 50,0 DKK	0,3 MW 44,0 DKK	0,3 MW 50,0 DKK	0,3 MW 3,0 DKK	0,31 MW 50,0 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	0,32 MW 2,00 DKK	
mFRR EAM	0,3 MW 45,0 DKK	0,3 MW 45,0 DKK	0,3 MW 45,0 DKK	0,3 MW 2,00 DKK	0,3 MW 44,0 DKK	0,3 MW 2,00 DKK	0,3 MW 3,0 DKK	0,31 MW 2,00 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	
Intraday	0,3 MW 45,0 DKK	0,3 MW 45,0 DKK	0,3 MW 45,0 DKK	0,3 MW 2,00 DKK	0,3 MW 44,0 DKK	0,3 MW 2,00 DKK	0,3 MW 3,0 DKK	0,31 MW 2,00 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK	0,32 MW 2,200 DKK



# Conclusion

## Key Takeaways

- Accumulation tanks are a proven enabler of thermal flexibility in district heating and industry.
- Optimized scheduling of electric boilers, heat pumps, and gas engines lowers operating costs
- Industrial and district heating customers need better tools for electricity market engagement, smart software accelerates the green transition
- **The business case is clear: flexibility infrastructure and smart operation deliver financial returns and environmental impact!**



# Contact me!

Christian Fuglsang

- [christian@fuglsang.dk](mailto:christian@fuglsang.dk)
- +45 26300955

Thank you for your time!

