

# Efficient production and use of hydrogen

The details that boost profitability

Dr. Sebastian Svanström & Dr. Oscar Lagnelöv

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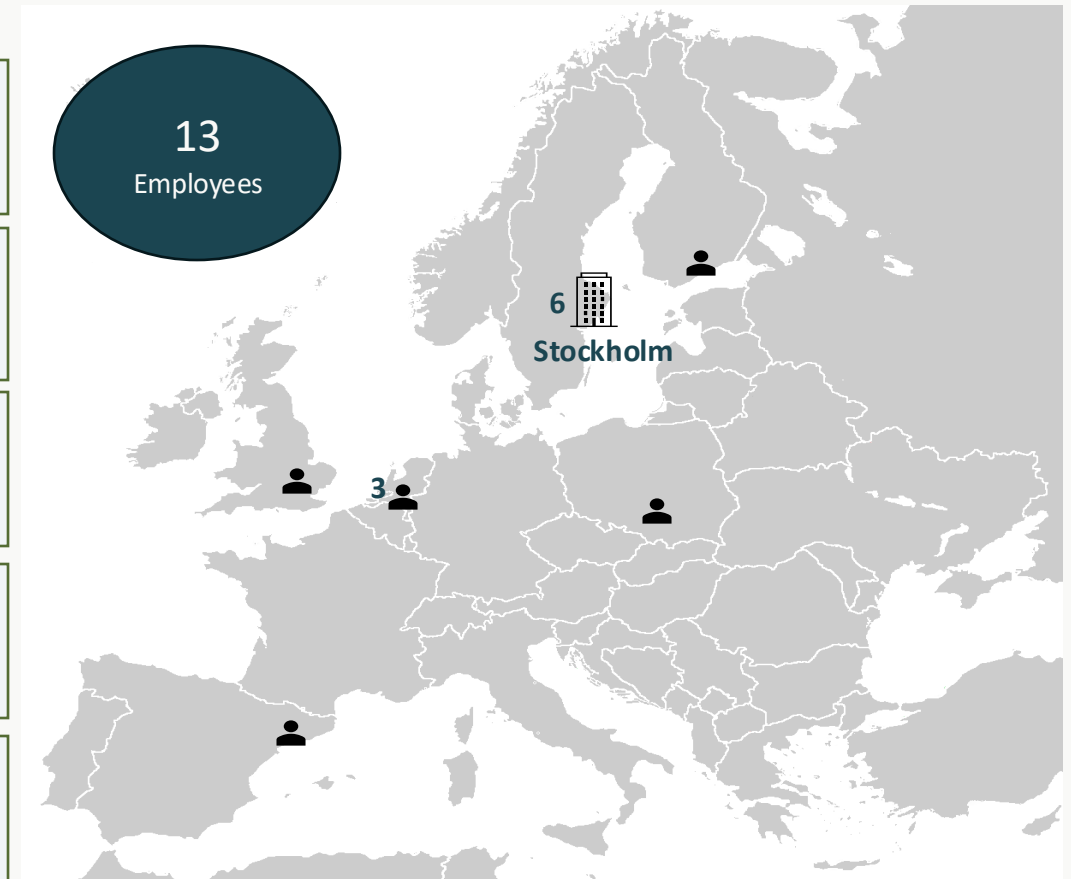
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# Quantified Carbon

An international consultancy driving **decarbonisation** of energy systems and industrial **electrification**.

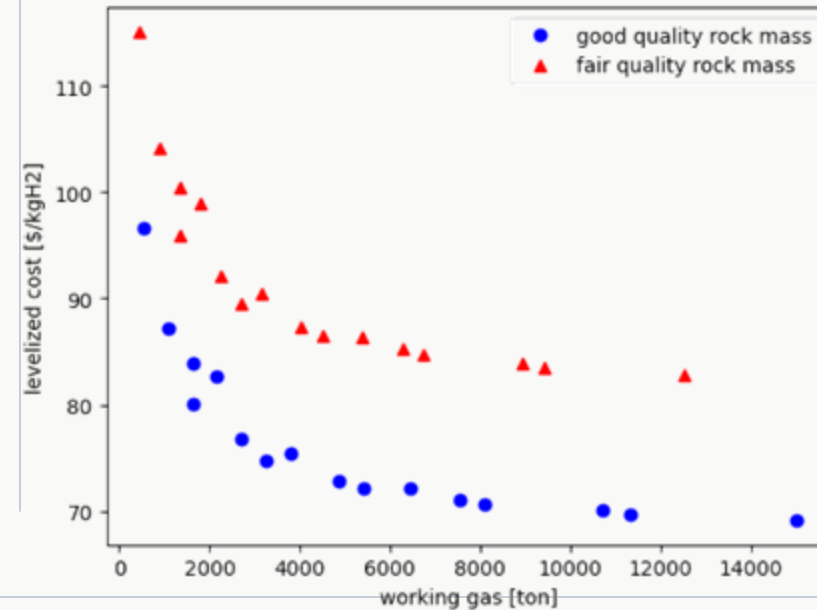
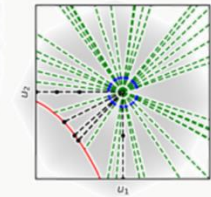
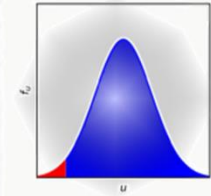
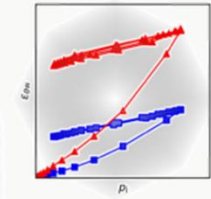
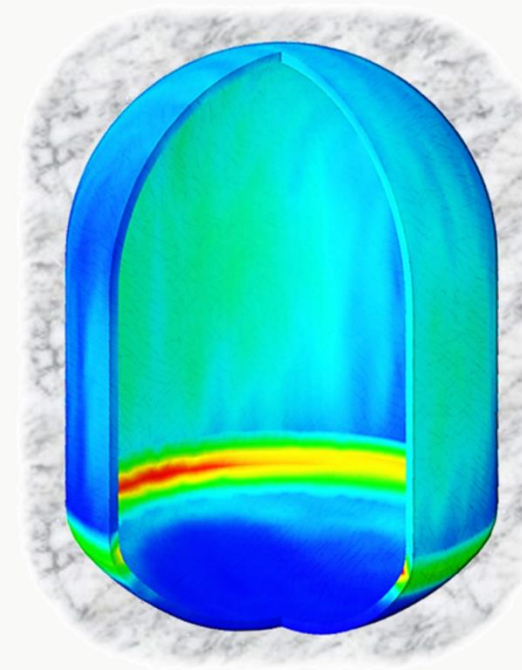
Founded with a shared commitment to reach global climate neutrality.

<b>Power System Studies</b>	In-depth analysis of decarbonisation scenarios to guide decisionmakers, stakeholders and the public.
<b>Power Price Forecasting</b>	Quarterly updated long-term market outlooks through 2050. On-demand scenario and in-depth parameter analyses.
<b>Industry Decarbonisation</b>	Detailed modelling of industrial processes and market outlooks to guide project design and investment decisions.
<b>PPA &amp; Portfolio Optimisation</b>	Portfolio optimisation integrating diverse assets, locations, and contract types to enhance sourcing, hedging, and risk management.
<b>Storage &amp; Co-location Optimisation</b>	Asset and infrastructure optimisation aligned with long-term market outlooks and variable parameters to guide project design and investments.



# Hydrogen storage

- QC possess in-depth knowledge of hydrogen storage methods
- QC employs one of the worlds leading experts on LRC-storage
- We offers tools for H<sub>2</sub>-storage on power system scales, as well as economic and physics based models



**Dr. Davi Damasceno**

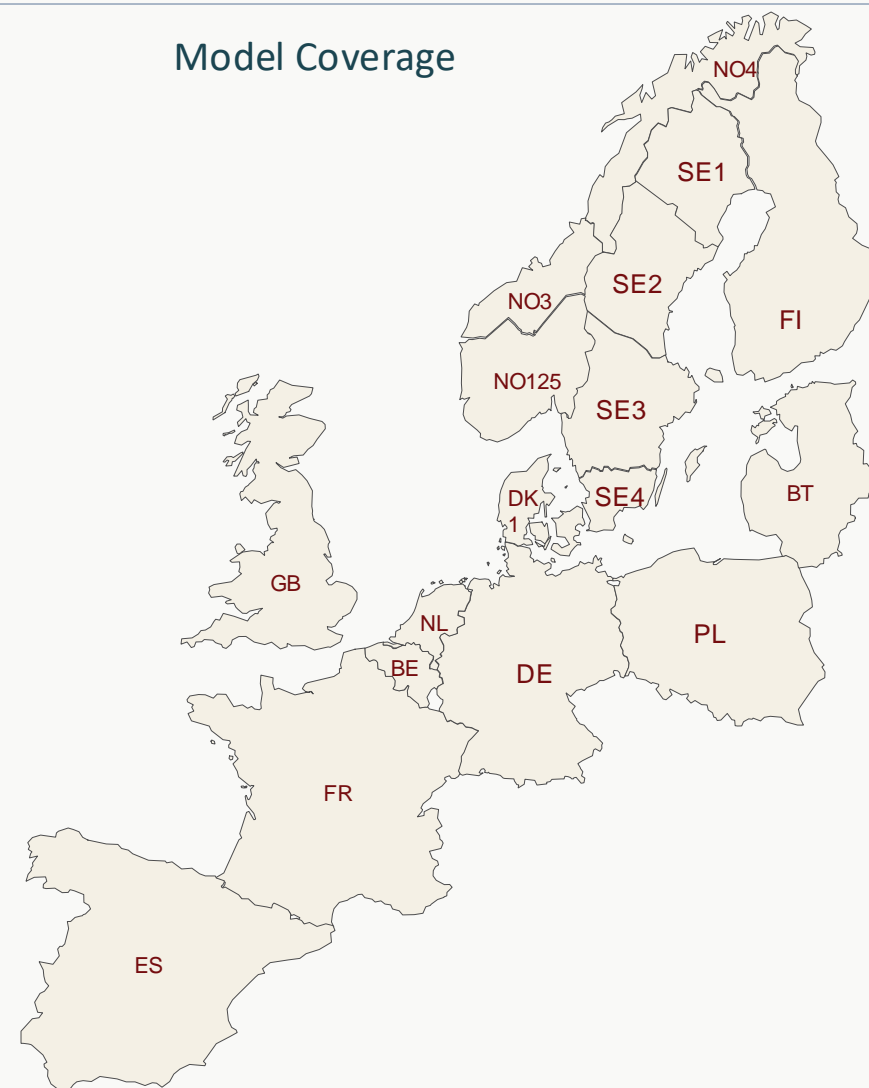
# Power market price forecasting

- Long-term power market forecasting is a core QC skill

In-house model – cGrid

Backed up by thorough data and market analysis

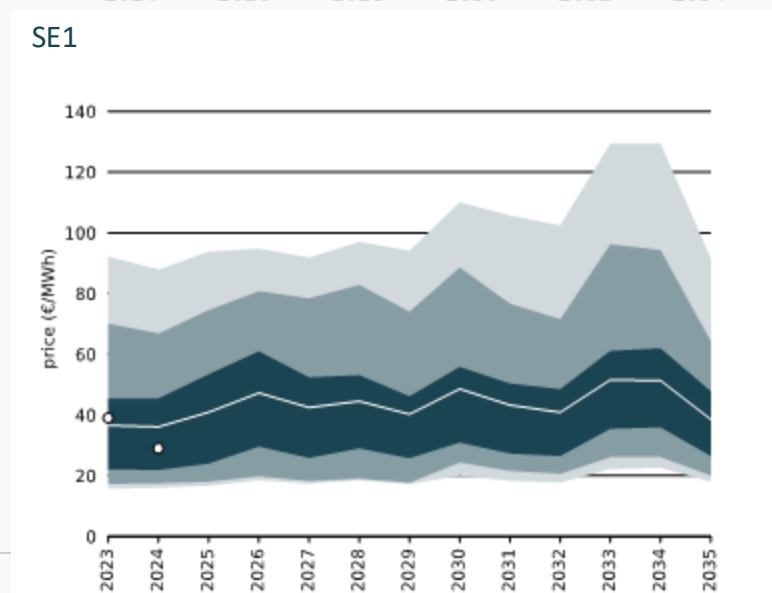
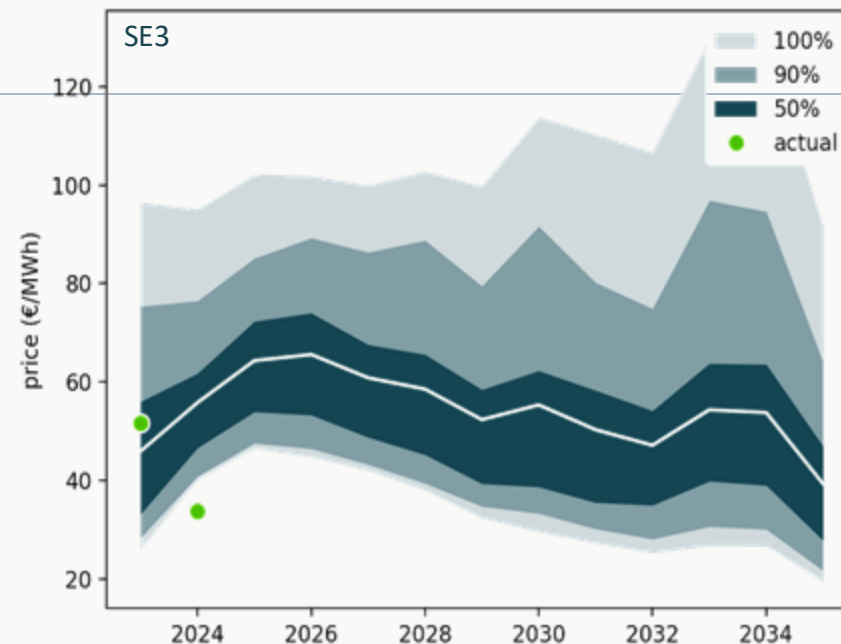
- No one can predict the future, but we can minimise surprises and explore the possible scenarios
- Combined with detailed modelling of industry processes it gives a high-level understanding of the interplay between market and actor



# Power market price forecasting

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  - In-house model – cGrid
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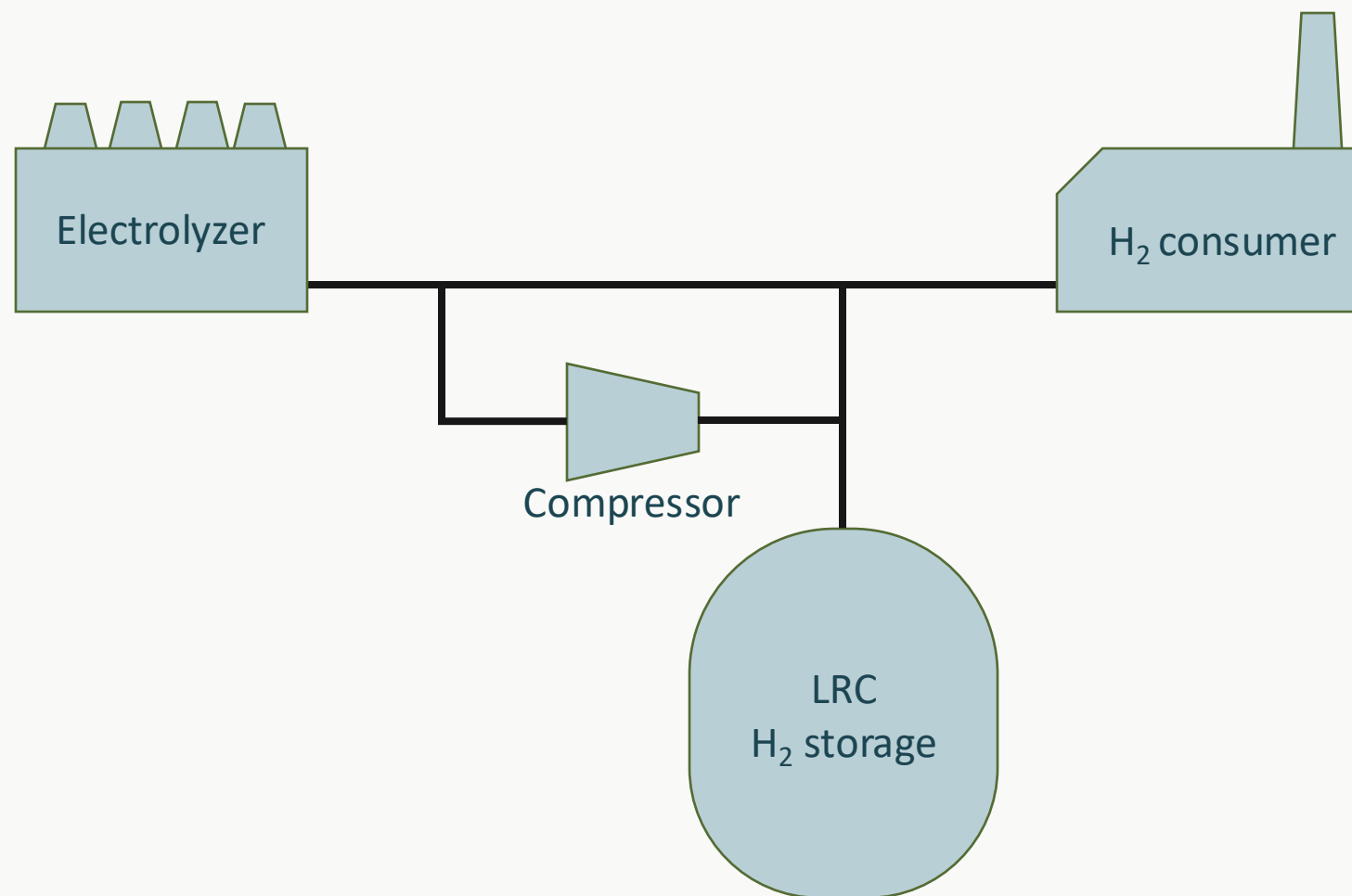
Spot price prognosis 2023-2035



# Hydrogen production with storage

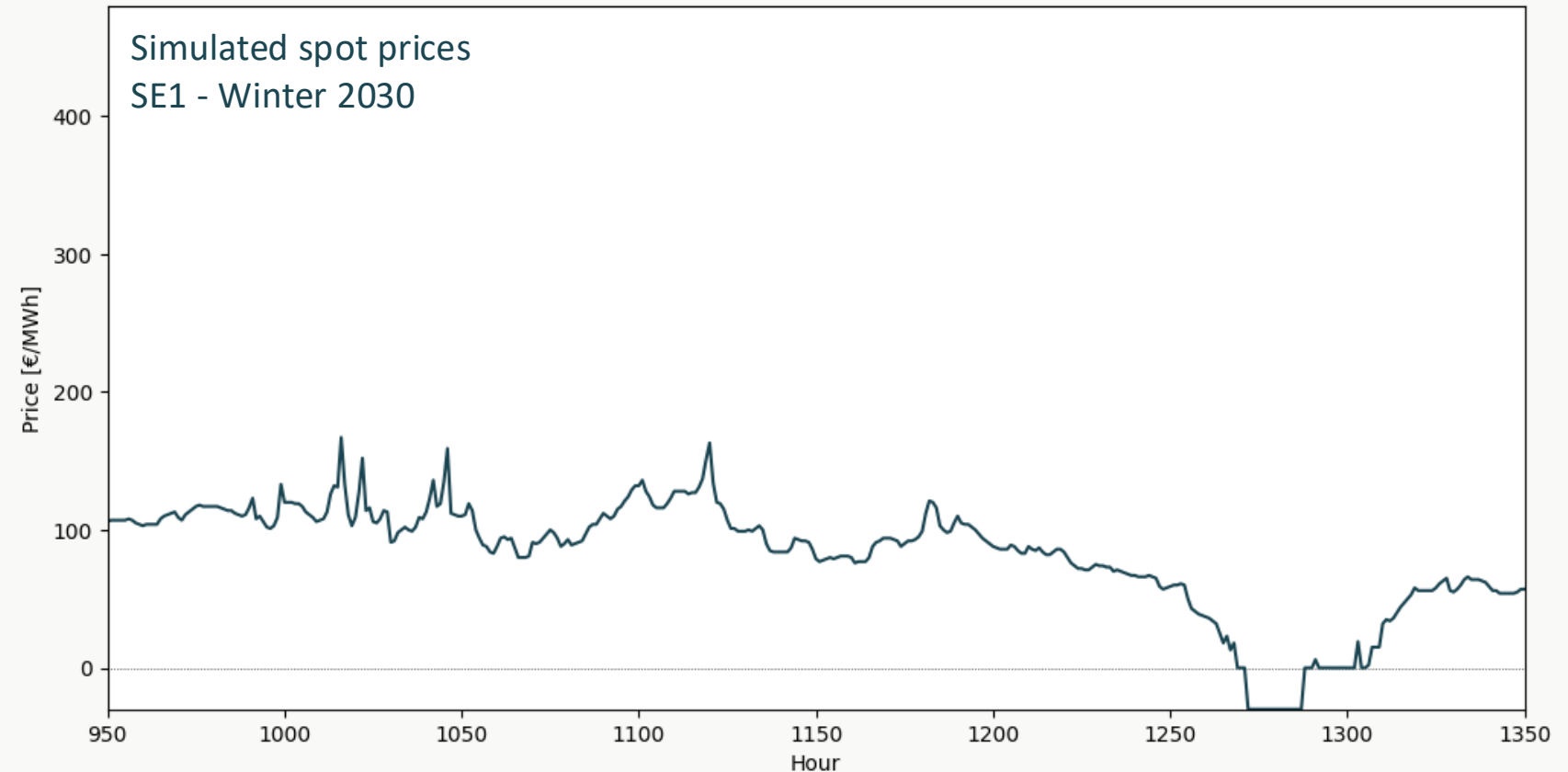
## What will we discuss & show today:

- Simulation of large hydrogen producers in SE1 as a key example
- Small electricity bidding zone
  - Peak power consumption  
≈ 1500 MW in 2022
- Large H2 consumers
  - LKAB, Fertiberia and Stegra with large scale electrolyzers
  - At least 1500 MW
- H2 production is optimized to minimize total cost, including:
  - Electrolyzer costs
  - Storage costs
  - Electricity and grid costs



# Large consumers in small markets

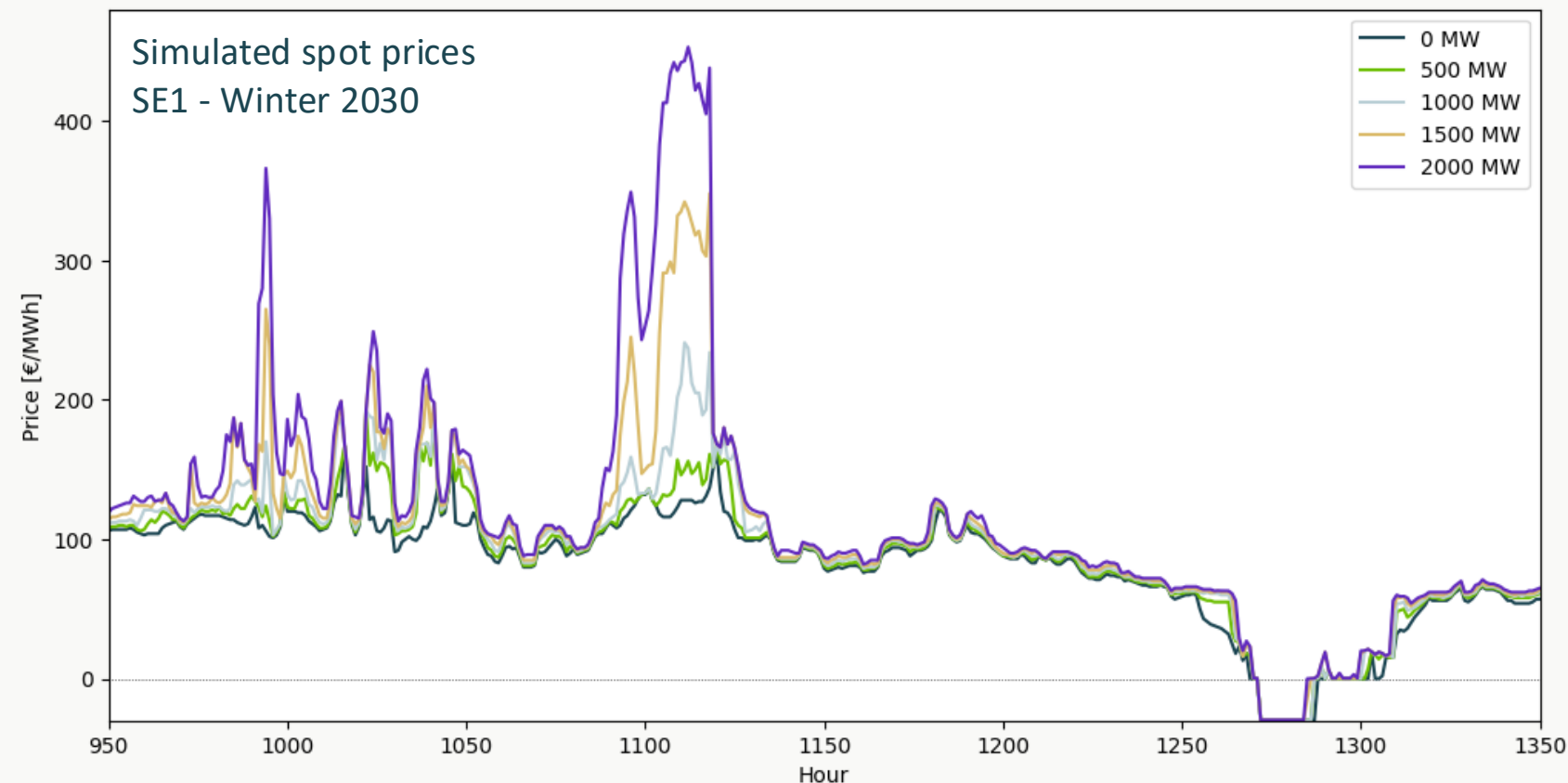
- For small consumers:
  - A single price for each hour of the year
- Set by the supply and demand on the market
  - When optimising a small facility its additional demand is negligible
- However, situation is different for large consumers





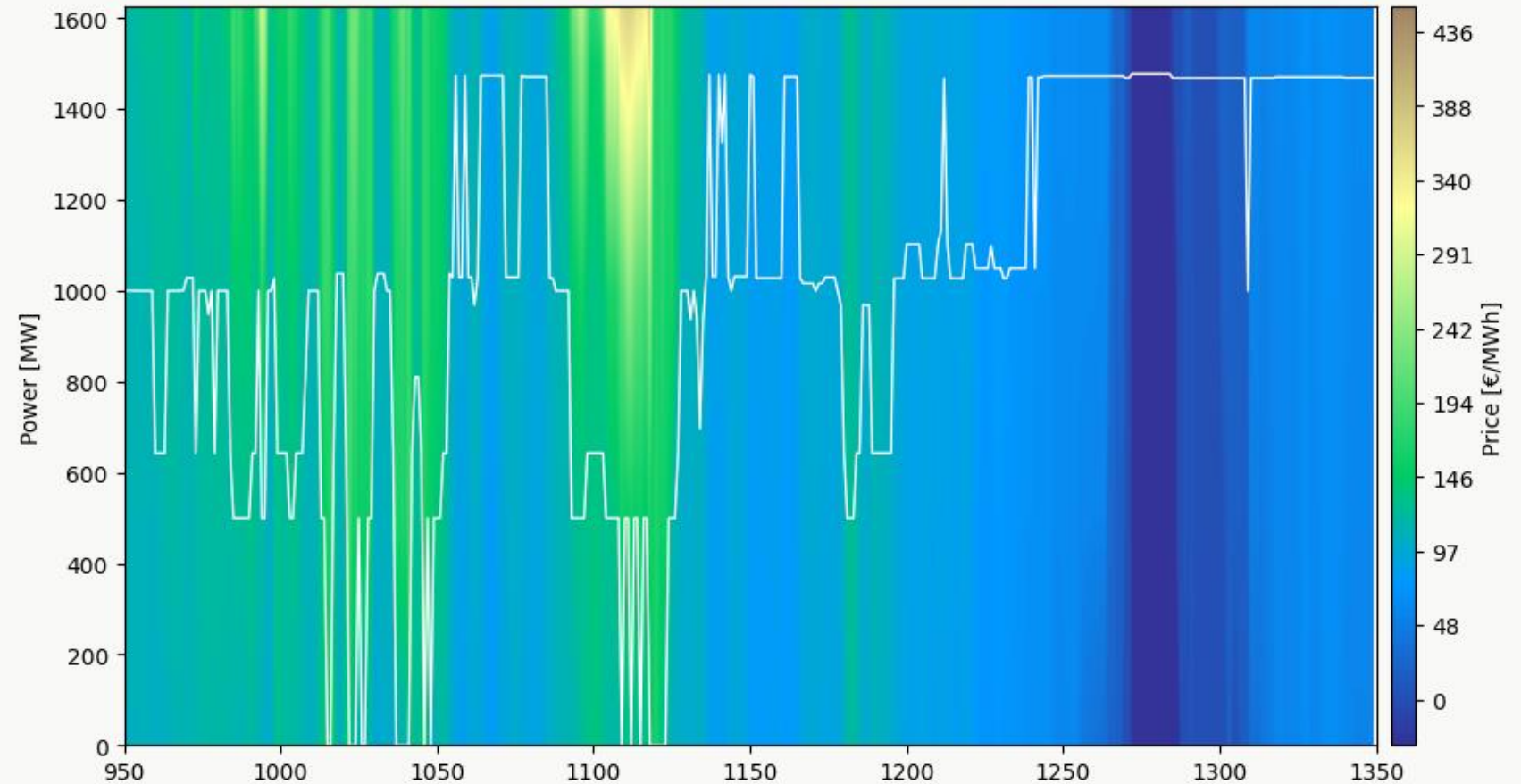
# Large consumers in small markets

- For large consumers:  
The price each hour is affected by your demand
- However, how much its affected is highly variable  
Depends on the price elasticity that hour  
Non-linear prices elasticity
- Essential to account for this in the optimisation of larger facilities  
This is our specialisation



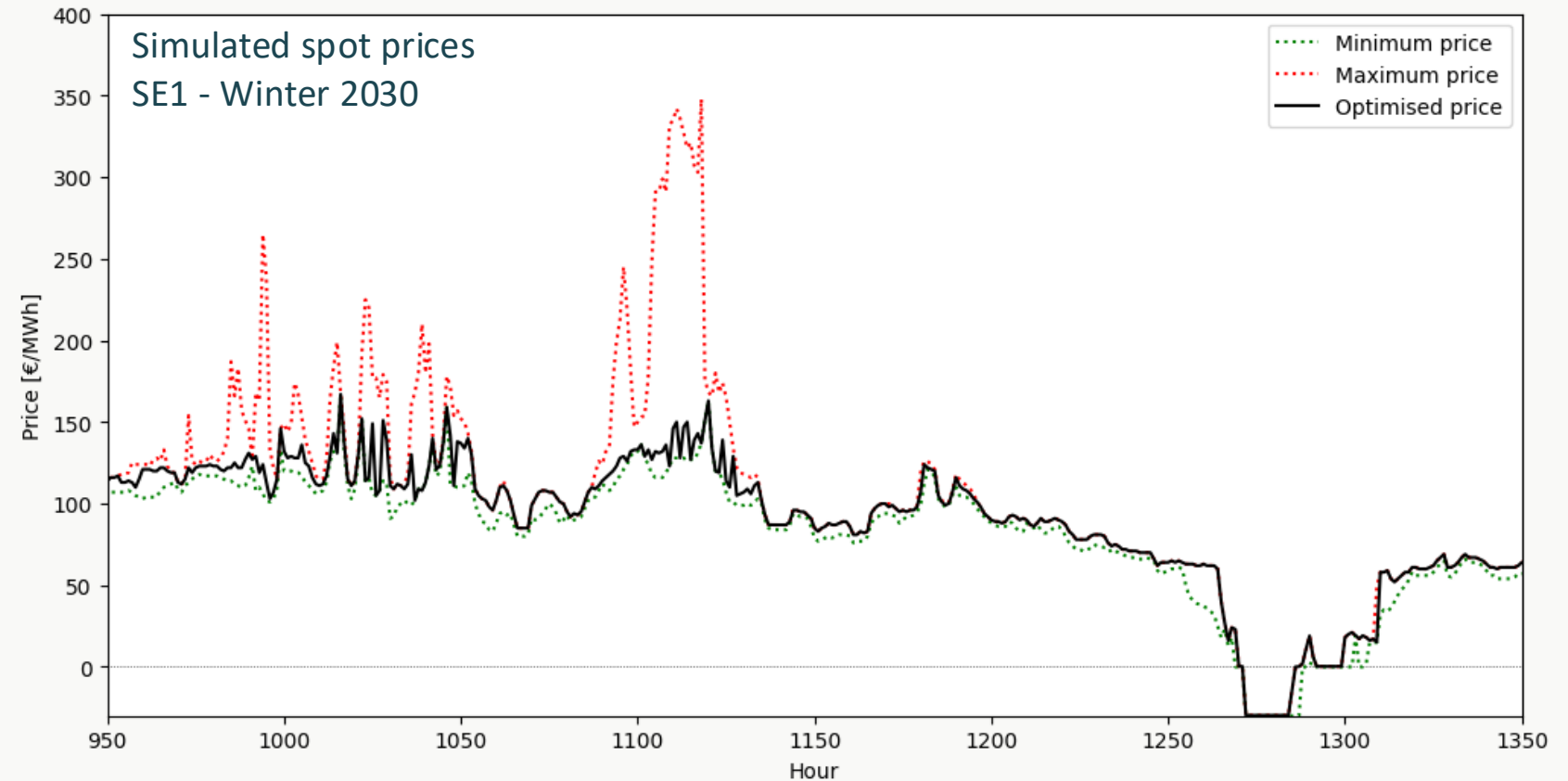
# Electricity market coupling

- How our model sees it:
  - Find the most cost effective investments to navigate a price landscape.
  - We can add PPA:s to this
- Discuss with me after the presentation if interesting



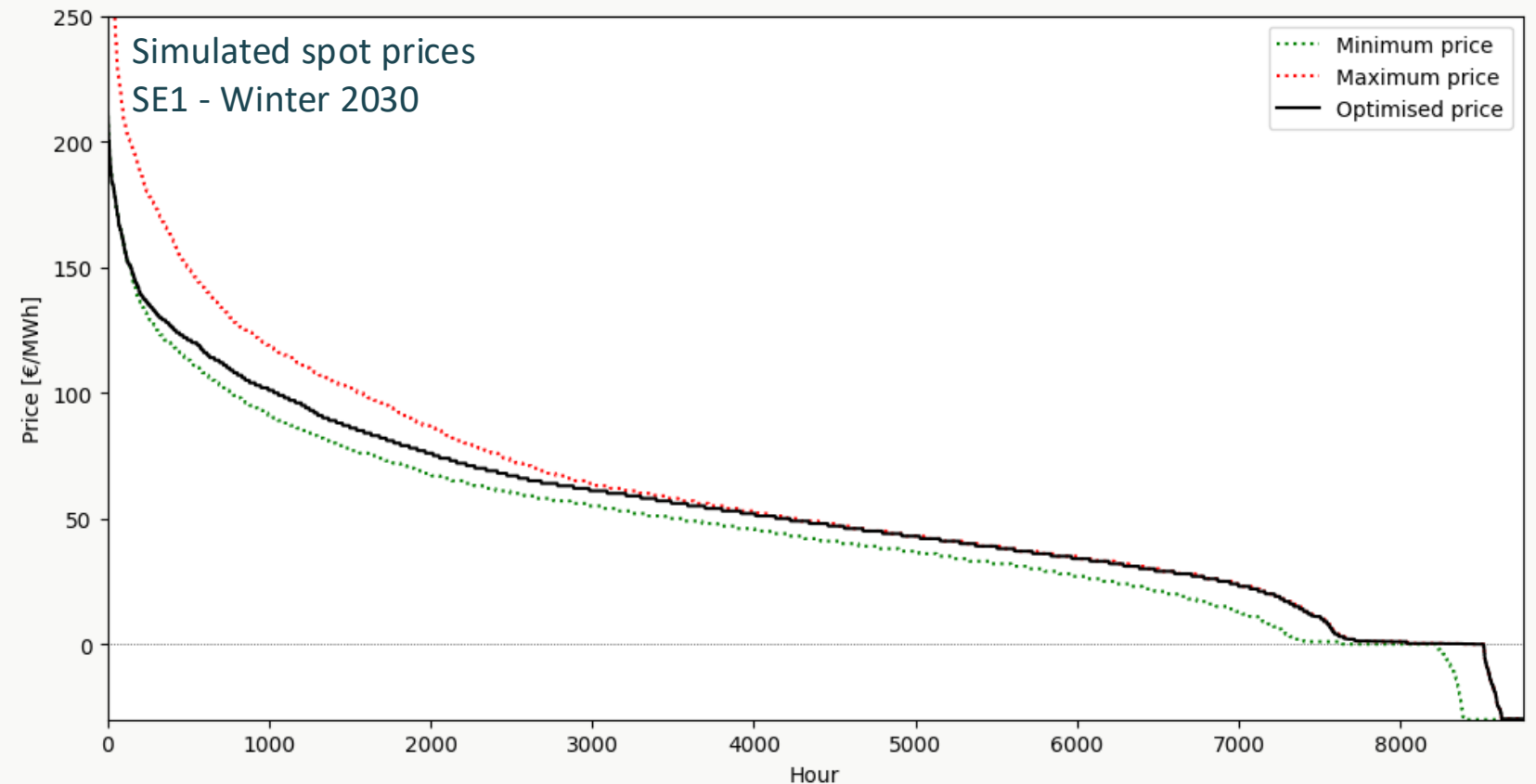
# Electricity market coupling

- Avoid high electricity prices while minimizing:  
Electrolyzer, grid, storage and compressor cost
- Significantly decreases price for H2 production:  
Without storage:  
58.8 EUR/MWh  
With storage:  
42.0 EUR/MWh (-28 %)
- Benefits are not only limited the H2 producer



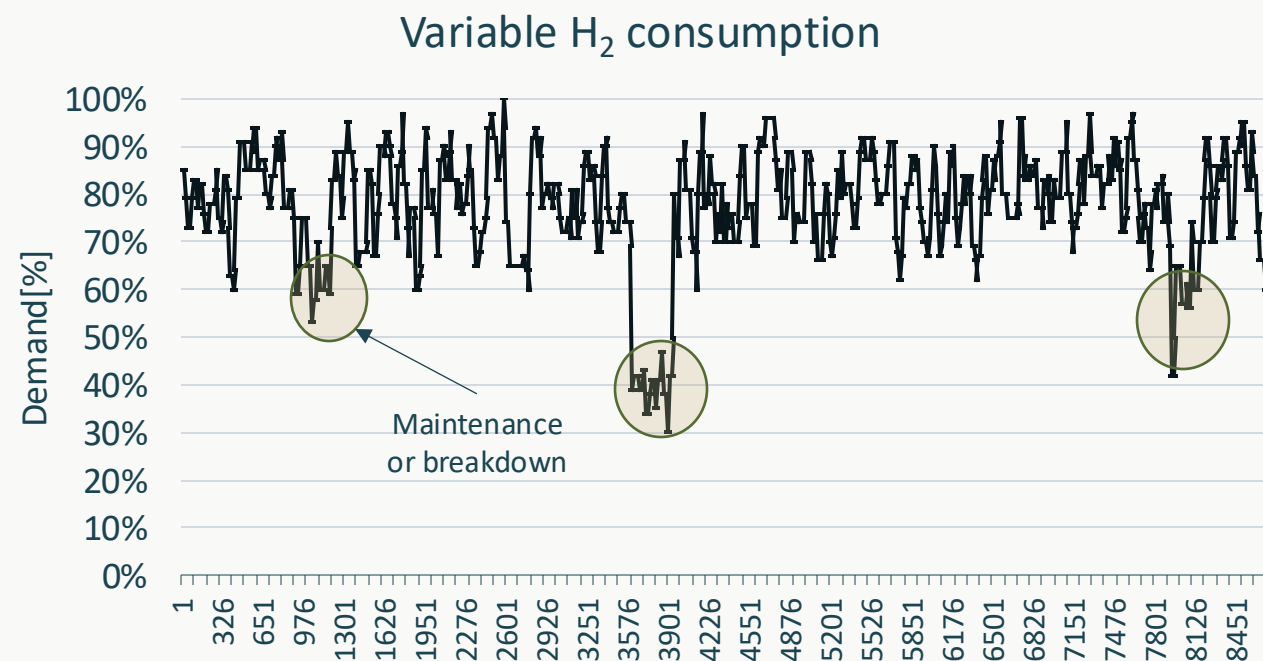
# Electricity market coupling

- Lower spot market prices
  - Without storage:  
58.0 EUR/MWh
  - With storage:  
52.3 EUR/MWh (-10 %)
- High electricity prices are virtually unaffected
  - Benefiting consumers with low flexibility
- Low/negative electricity prices increase significantly
  - Benefit power producers



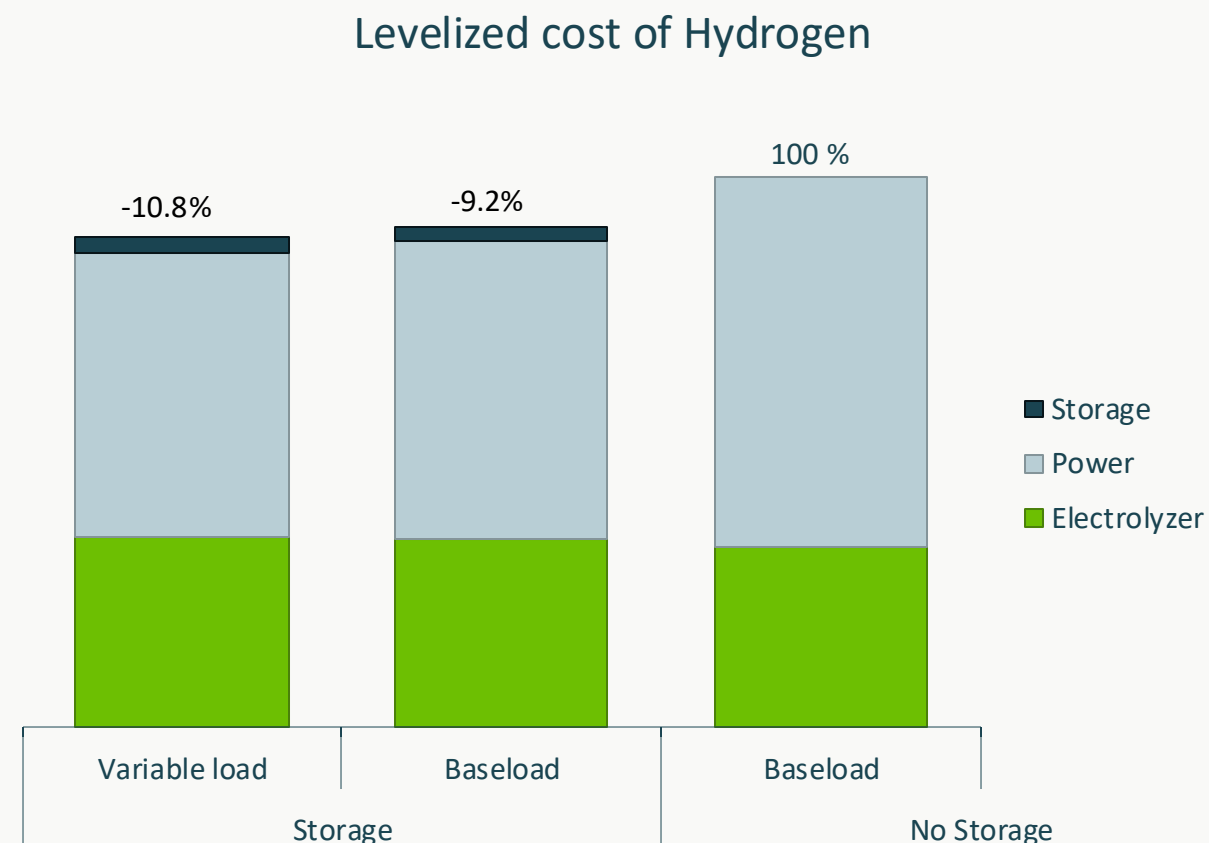
# Storage effects on electrolyzer sizing

- A realistic, variable H<sub>2</sub> consumption with stops, maintenance and was simulated and optimized
- Storage capacity:  
≈ 3 days of peak H<sub>2</sub> consumption
- Electrolyzer capacity:  
Variable: 97% of peak H<sub>2</sub> consumption  
Baseload: 123% of peak H<sub>2</sub> consumption
- A commonly mentioned problem is that filling of the storage require larger, more expensive, electrolyzers  
Variable consumption and stops used to fill storage  
In some cases, less electrolyzer capacity are needed with storage than without



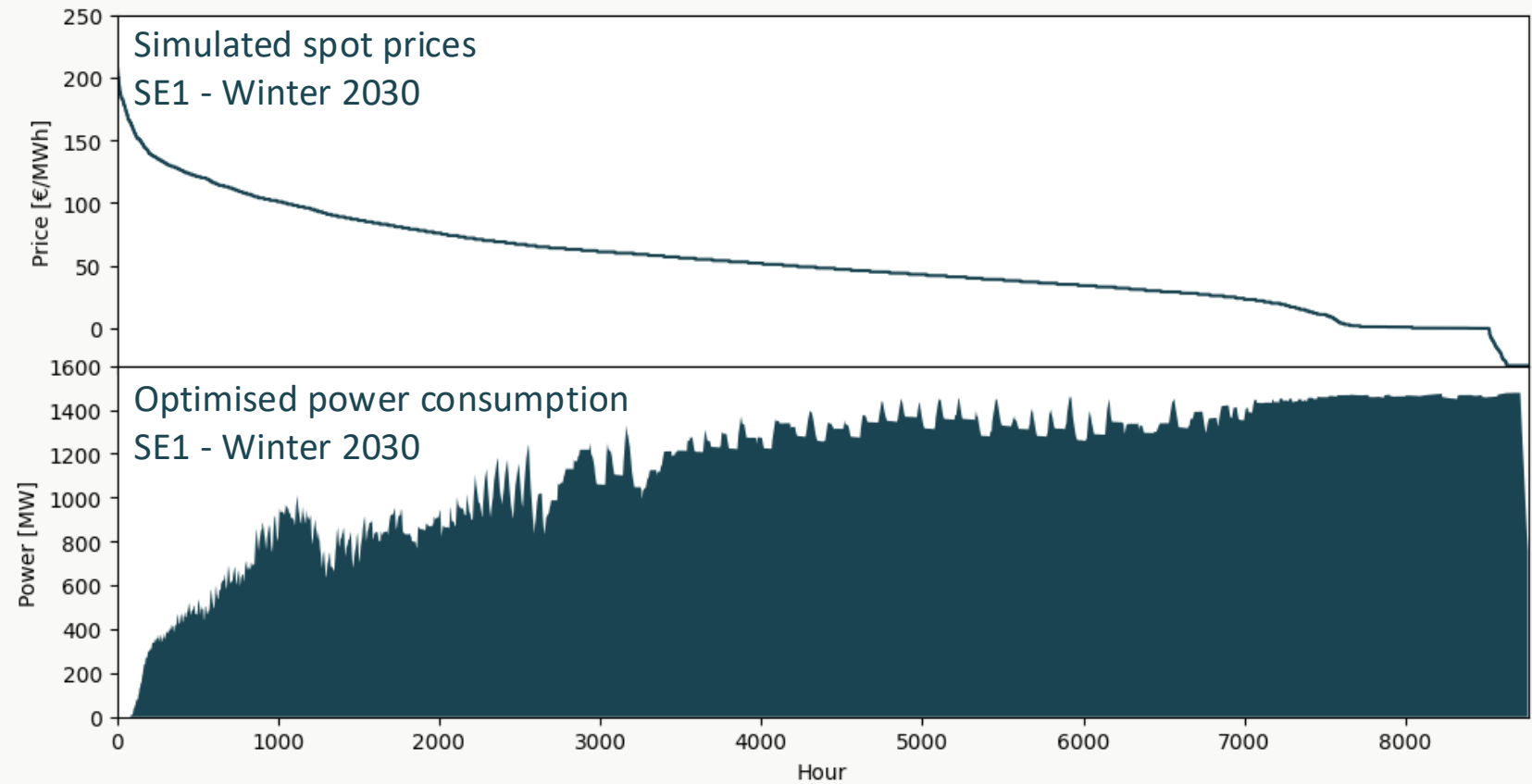
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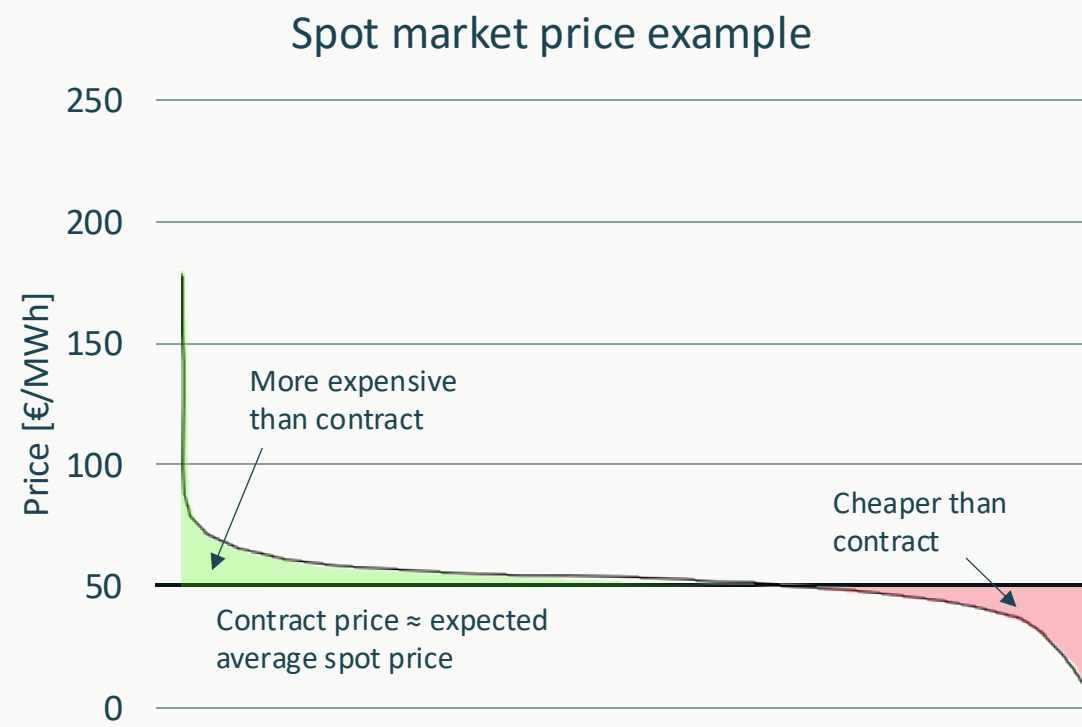
# Flexibility and hedging

- No need to hedge for short term spot market volatility
  - Flexibility allows H2 production to avoid the highest price hours – inherent risk avoidance
  - H2 production is shifted to low price hours
- Spot market volatility can be positive, rather than negative



# Hedging – Avoiding high costs (and high profitability?)

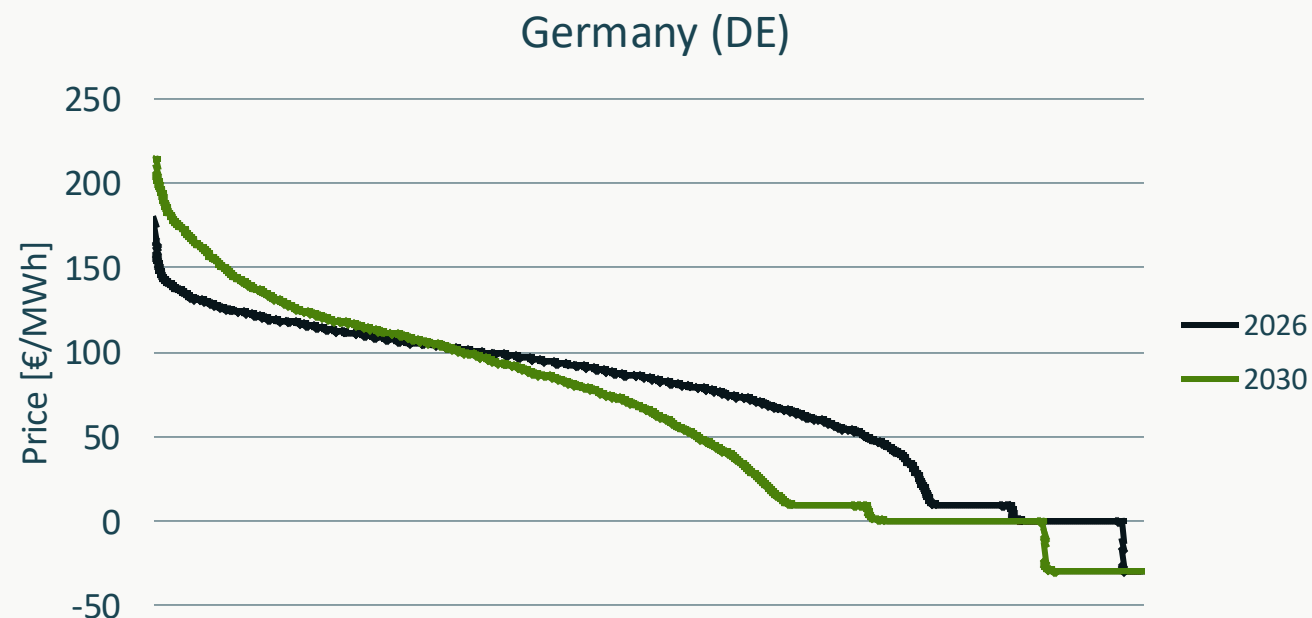
- Hedging is a normal strategy to avoid or limit risks
  - Safely predict the cost of energy
- Energy demanding industries often sign PPA:s to
  - Limit exposure to spot market volatility (price within a year)
  - Limit future price risk (price between years)
- However, this might also limit the profitability
  - The volatility of the spot market can also lead to opportunities
  - Electrolyzers with storage provide flexibility to achieve low power cost, which producing low-cost H<sub>2</sub> requires





# Hedging

- Forecasts predicts more intermittent production in all markets
- This means in general that more hours will be cheaper than PPA contract prices
  - Contract price based on average price
  - Germany (DE): 38% → 48 %
- Avoiding 20% of the most expensive hours via flexibility lowers the average price
  - ≈10% (2026) and ≈ 20% (2030)
  - A new type of hedging required
- By locking in the price, H<sub>2</sub>-producers miss negative or very low prices.



**Avoiding risk**  
VS  
**Profiting on low prices**

# Key takeaways

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- Electricity prices are load dependent
  - Essential to account for these effects when optimising H<sub>2</sub> production (and power purchasing strategy)
- The addition of H<sub>2</sub> storage significantly lowers both power prices and the market prices
  - Increases the lowest prices, but does not increase the peak prices
  - Furthermore, the required electrolyzer and storage capacity is relatively small
  - The electrolyzer capacity may even be smaller with storage than without
- Hedging can increase LCOH, as lowest cost hours can not be used
  - The high-cost hours could be avoided with flexibility or storage
  - A new type of hedging, to only deal with future price risks, might be required



# Thank you

**Dr. Sebastian Svanström & Dr. Oscar Lagnelöv**

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