



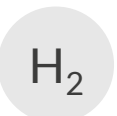




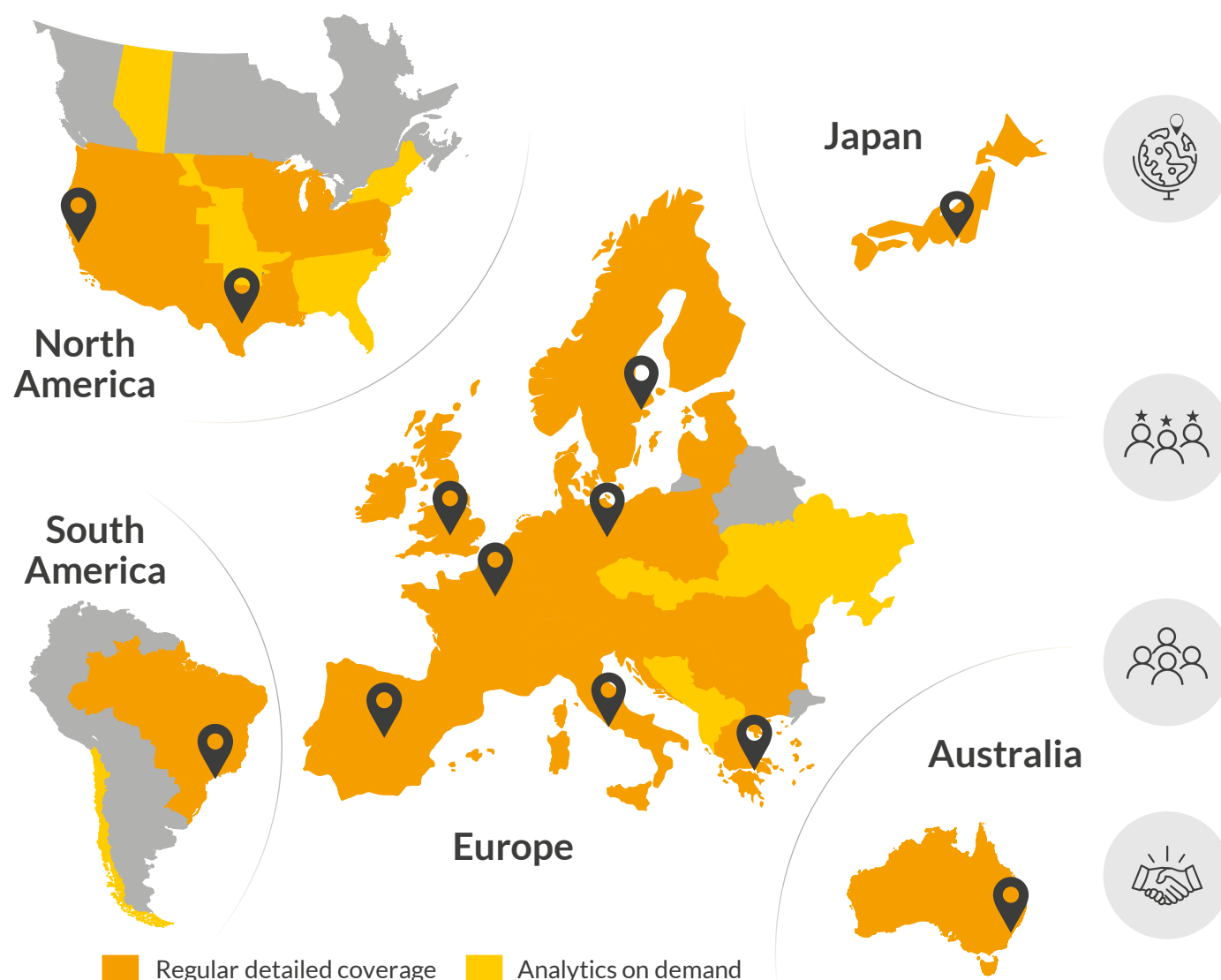
# Do change the running system - Optimizing battery revenues across markets

September 2023



# Aurora provides market leading forecasts & data-driven intelligence for the global energy transition

- Power markets 
- Renewables 
- Storage 
- Electric vehicles 
- Hydrogen 
- Carbon 
- Natural gas 



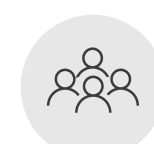
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## 700+

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## 150+

transactions supported in 2022

# We work with a very broad range of clients, assisting them with analysis that underpins their most Important decisions and transactions








## Flexible generation



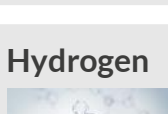
-  Green Frog Power, support for £100m debt financing of gas peakers by Lloyds, HSBC, NIBC
-  Battery investment strategy and sizing analysis for PE-backed Spanish renewables developer
-  Gas peaker and battery storage portfolios, sell side advisory for UK Power Reserve
-  German battery storage market strategy development for a major Infrastructure investor
-  Battery storage, support equity and debt raise ahead of DS3 auction
-  SIPS battery storage (300MW/450MWh) In Victoria, supported Neoen in project debt financing by CEFC










## Thermal generation



-  Buy-side DD of 480 MW CCGT for major equity fund
-  Evaluation of a high-temperature heat storage technology for a major German utility
-  Cory Riverside EfW plant, advisory for successful bidder
-  EfW plant, buy side advisory for final bidder
-  Bidding strategy development for participants In Germany's coal closure auctions
-  District heating decarbonisation strategy development for a major infrastructure developer
-  Support of financing of a newbuild CCGT asset




## Renewable generation



-  Onshore wind, sell side market advisor for 400MW subsidy-free project
-  Merkur offshore wind farm, sell-side advisory for Partners Group
-  Potegowo 220MW onshore wind, supported the debt financing of €49m provided by EBRD
-  Borssele 3&4 offshore wind farm, buy side advisory for the successful bidder
-  Market entry support for an oil & gas company diversifying into renewables
-  Race Bank offshore wind farm, advisor to successful buyer Macquarie
-  Wento renewables portfolio sale to Equinor, sell-side market advisor
-  Buy-side for major European Infra fund into +200MW solar farm with batteries in Australia
-  Market analysis for sovereign wealth fund looking to provide mezzanine debt to large Spanish wind and solar developer





## Hydrogen



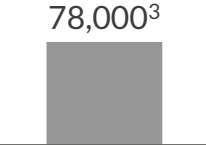
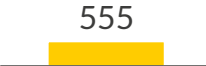
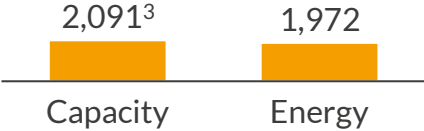
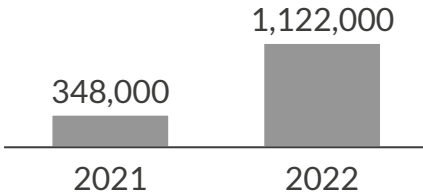
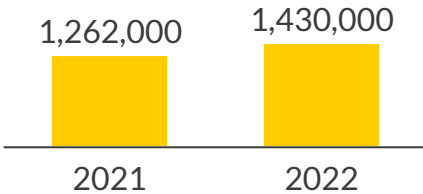
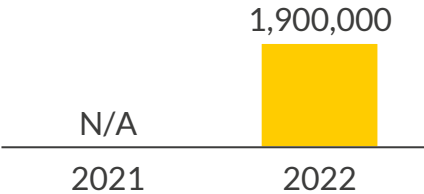
-  Localised hydrogen demand sizing for a major German utility
-  Assessment of hydrogen fuel switch option and economics for a CCGT
-  Evaluation of H2 transport cost to North-Western Europe for a solar hydrogen project developer

## Oil & gas



-  UK National Grid distribution network (>£8bn), buy side advisor for successful bidder consortium
-  TransitGas pipeline, buy side advisor for successful infrastructure fund
-  Eustream, commercial advisor to obtain credit rating for ~€1.2bn bonds
-  North-Sea gas upstream asset (>€4bn), advisor to successful bidder

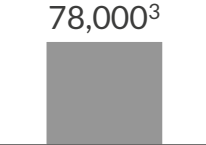
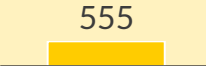
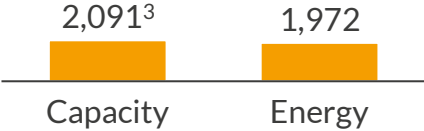
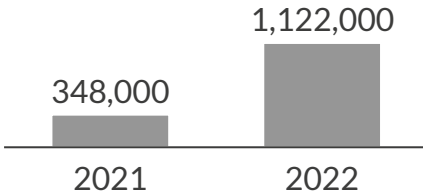
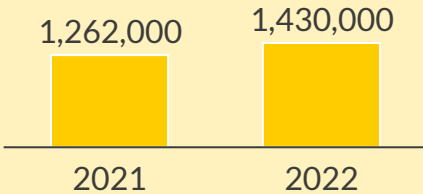
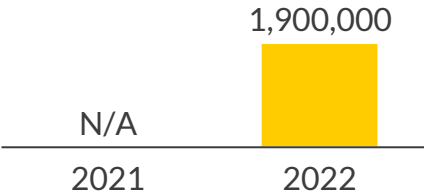
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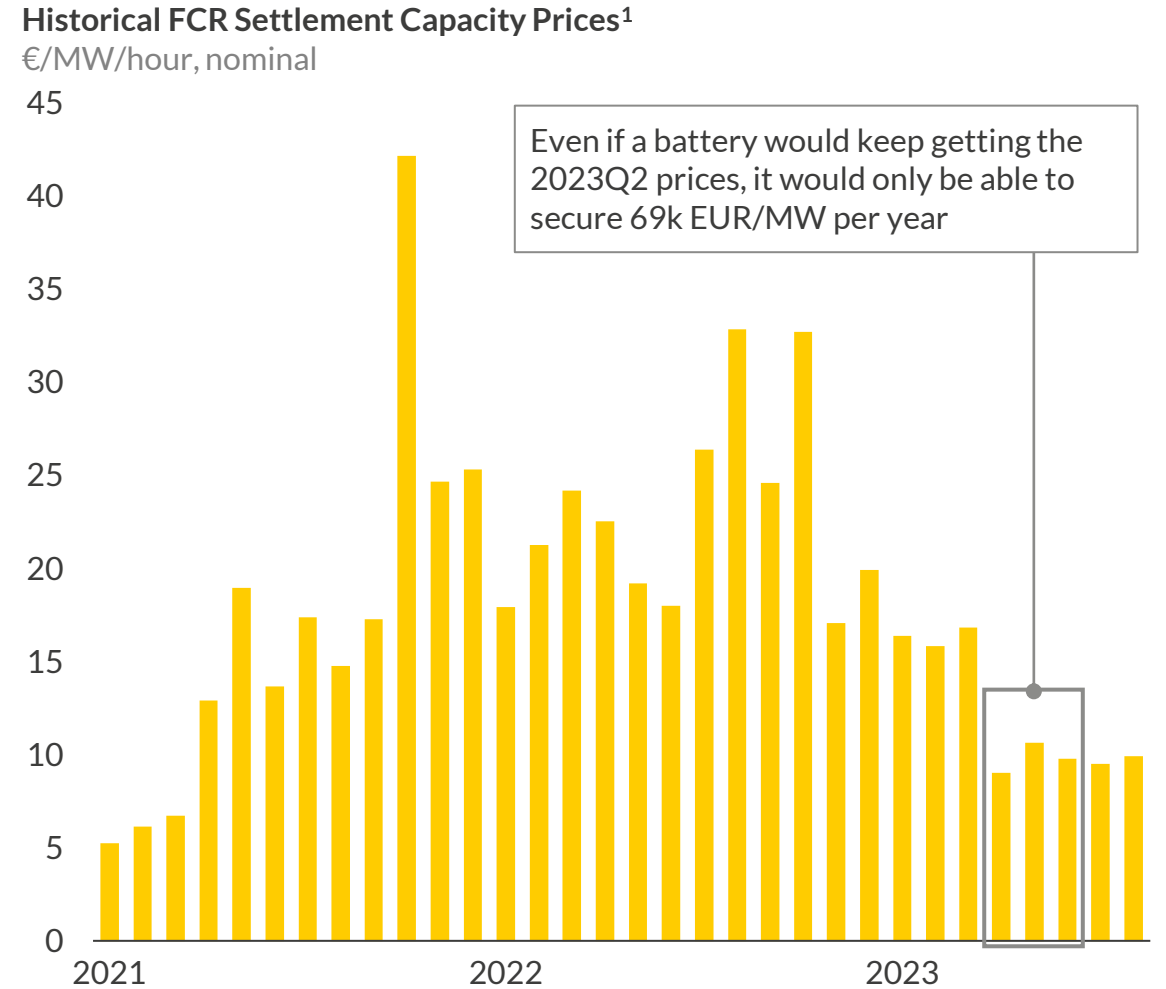
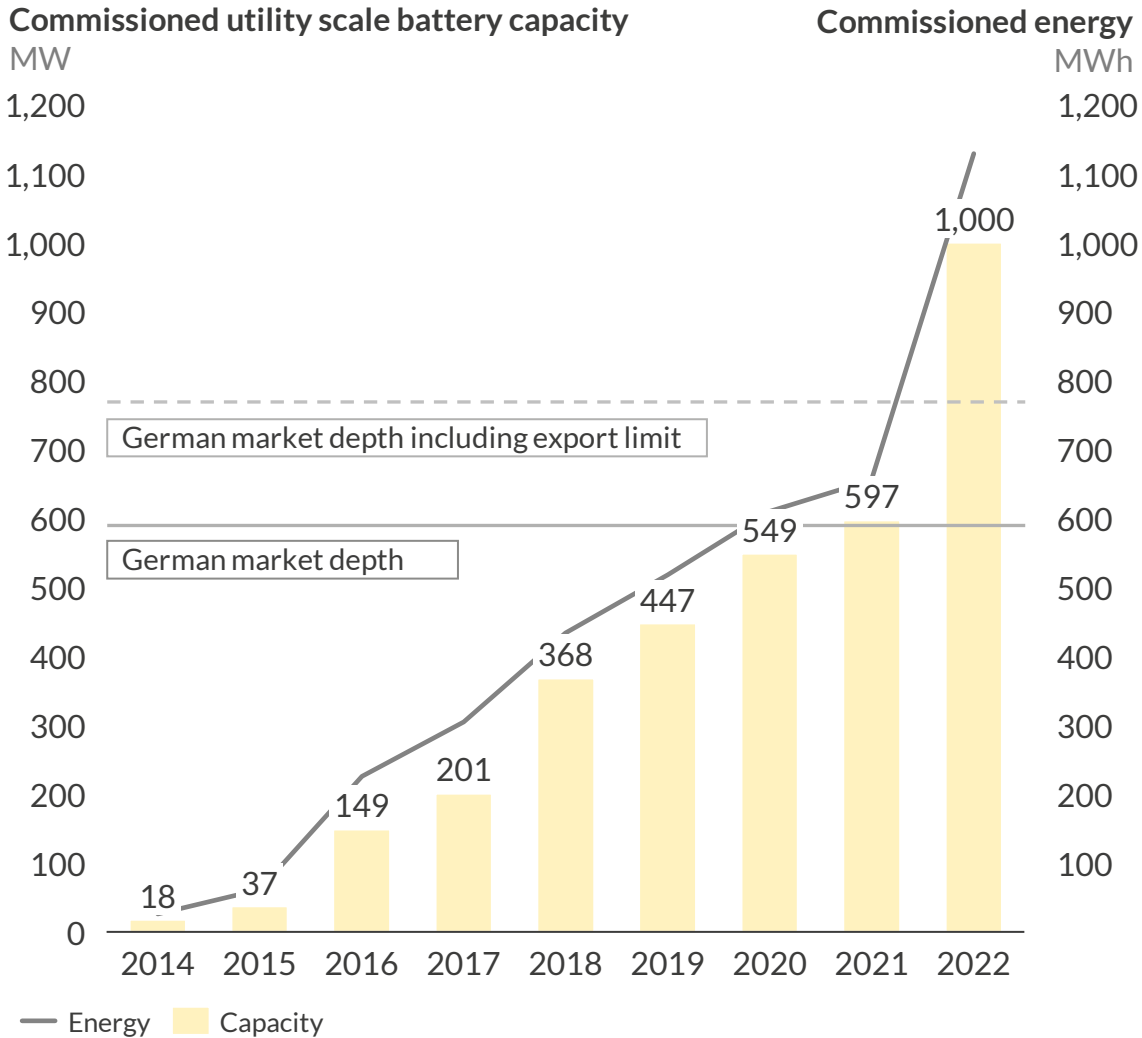
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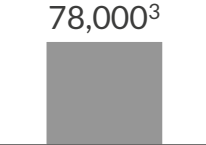
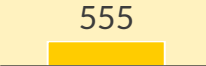
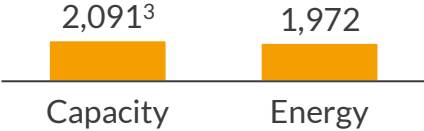
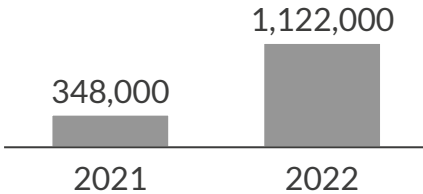
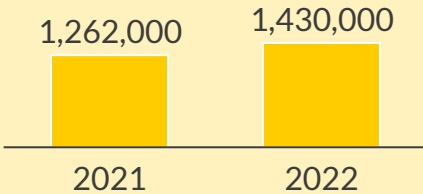
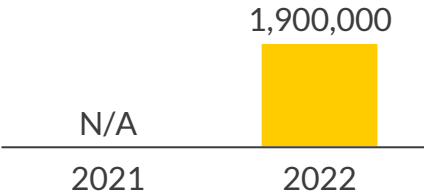
# Due to market saturation, relying on FCR only would be a risky business model A U R R A



1) Opening of the FCR Cooperation in July 2020.




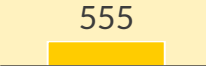
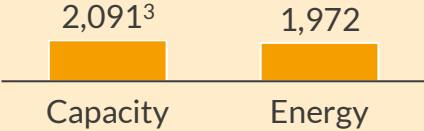
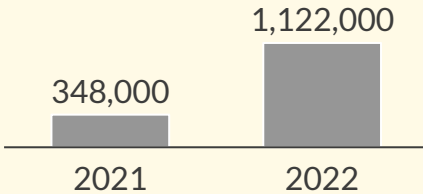
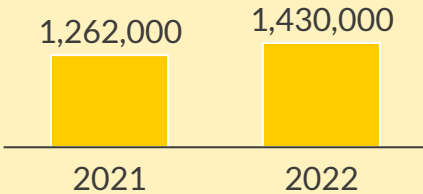
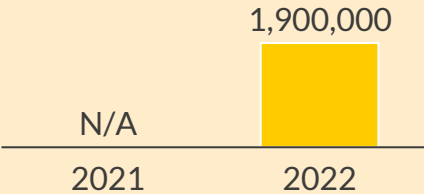
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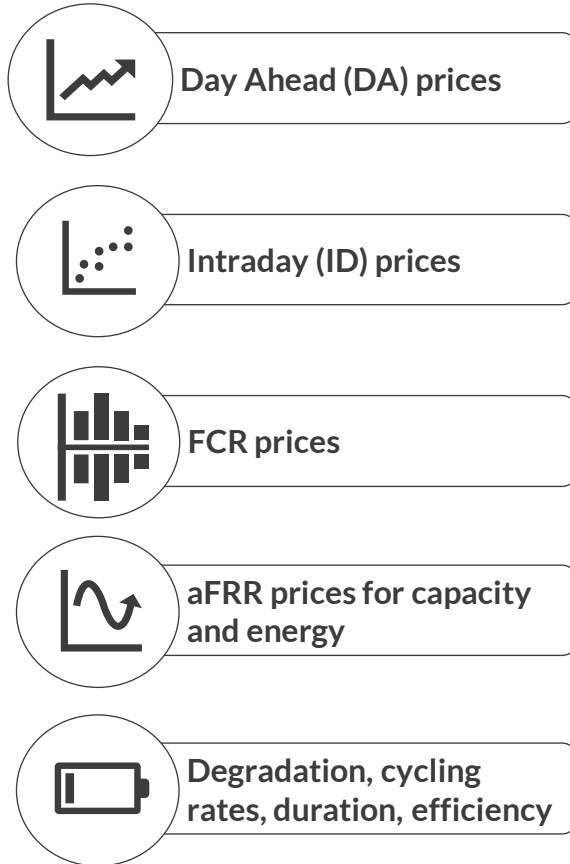
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# Aurora models battery business cases in two stages based on our in-house market forecasts and realistic battery trading algorithm

## Flexibility markets and battery parameters



## Realistic battery trading algorithm

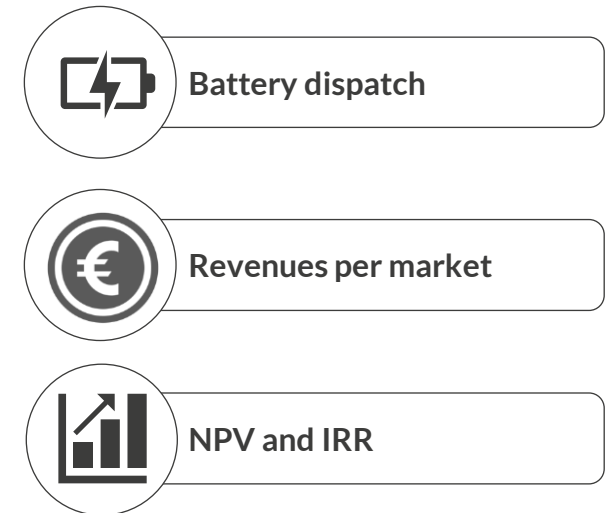
### 1 Optimisation process for Day Ahead markets

- Optimisation of markets that take place Day Ahead (Day Ahead, aFRR capacity and FCR markets).
- We assume perfect foresight of two days, but batteries can only take decisions for the next 24h.
- The model solves for actions in these markets simultaneously.

### 2 Dispatch based on real-time knowledge

- Batteries have limited foresight into Intraday prices (until next committed Day Ahead trade)<sup>1</sup>.
- Battery gains insight into aFRR energy markets in real time.
- Based on results of stage 1, battery charges or discharges if within-day market prices are more attractive than planned actions.
- Model accounts for upcoming commitments and applies penalties for missed actions.

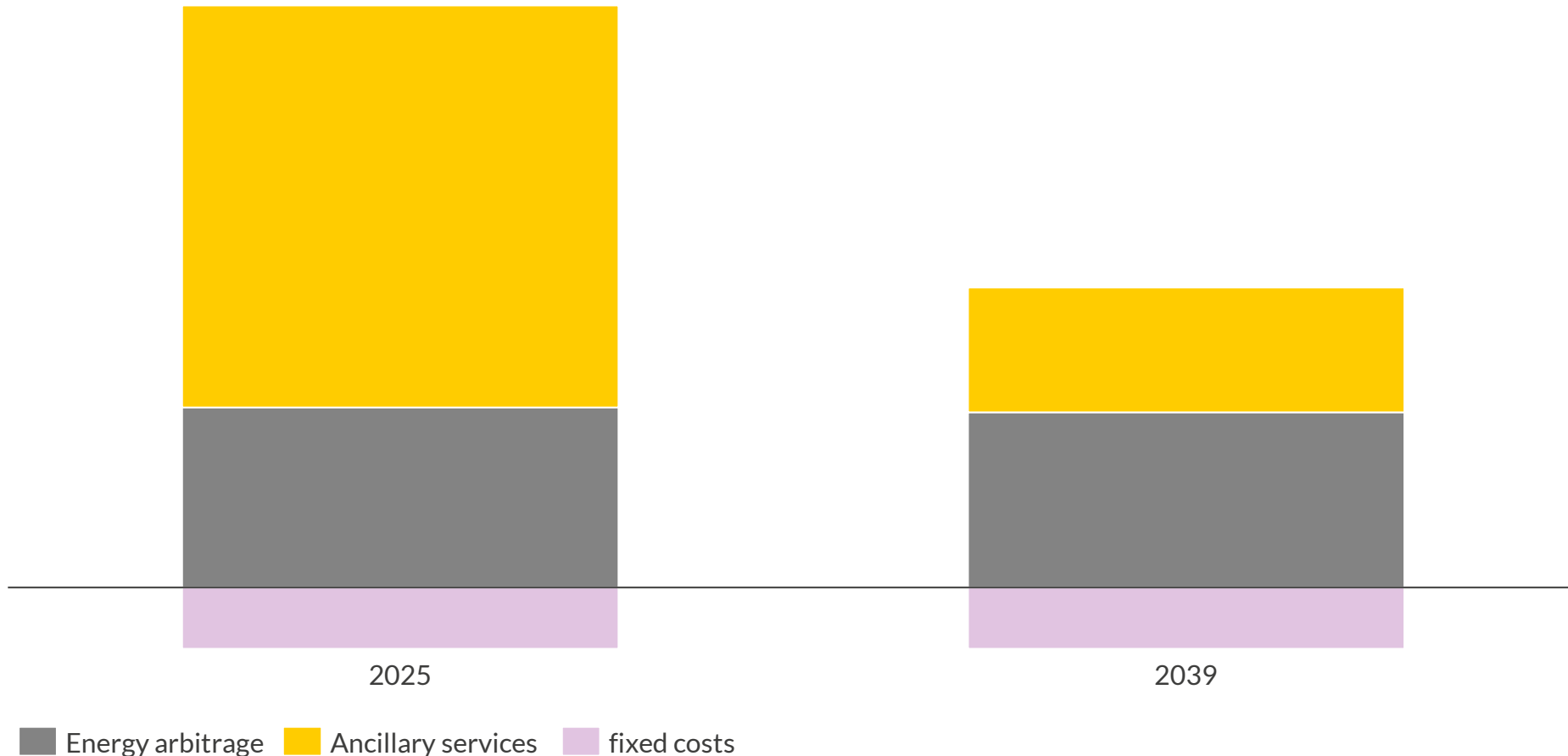
## Results



1) Limited Intraday forecast based on the assumption that battery needs to optimise state of charge with regard to upcoming committed trades, i.e. in the Day Ahead market.

# Revenues from all markets decrease due to battery degradation, market saturation and lower price levels


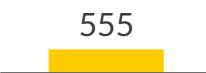
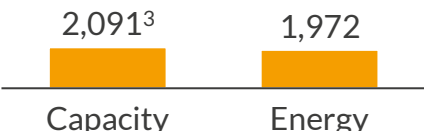
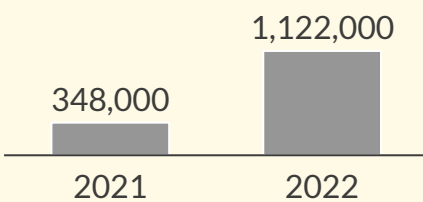
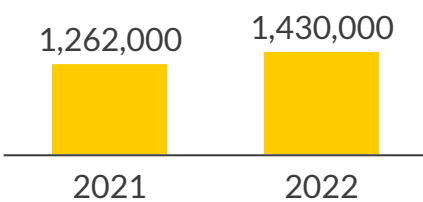
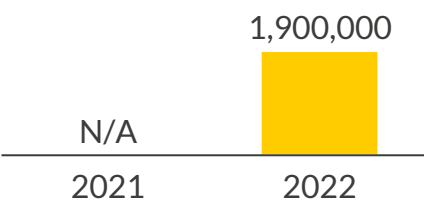
Revenues and costs for a 2h battery system with entry year 2025  
 €/kW, real 2022



## Revenues and costs of a 2h battery system

- Revenues of 2h battery system decrease towards the end of its lifetime for multiple reasons:
  - **Battery degradation.** Every time the battery charges and discharges, it loses duration. By the end of its lifetime, only 63% of its initial duration are left, leading to lower total gross margins.
  - **Saturation of aFRR capacity and FCR.** The market entry of batteries will saturate the aFRR capacity and FCR, leading to lower revenues.
  - **Decreasing price levels on wholesale markets (Intraday and Day Ahead)** lead to lower spreads. While 2027 power prices are still high due to the aftermath of the commodity crisis, power prices will drop in the 2030s.

# Wholesale markets and ancillary services are the key sources of revenues for batteries

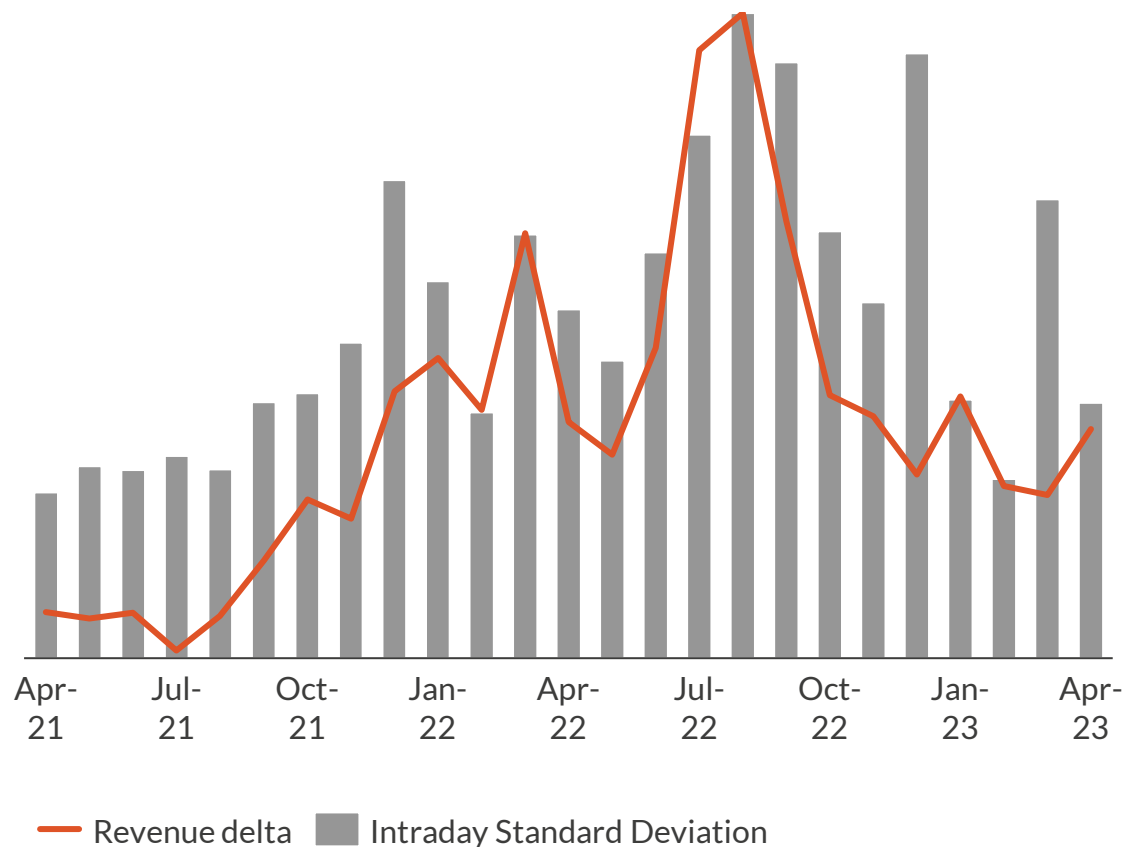
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# The higher fluctuations on the Intraday Market, the more important advanced trading strategies

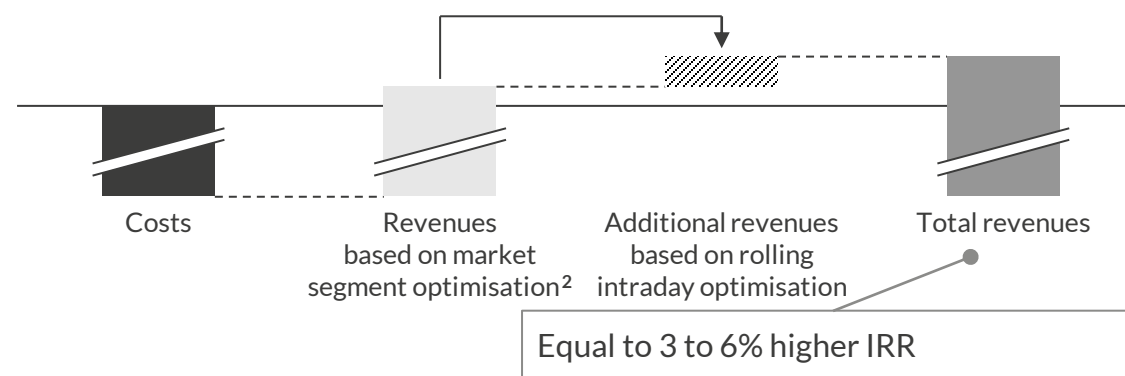
Increasing volatility of the wholesale markets leads to a higher gap between advanced trading strategies and Auroras trading strategy



Technologically advanced trading strategies, for example algorithmic trading, can help securing higher arbitrage revenues

- Compared to fundamentally modelled revenues generated by optimisation on wholesale and ancillary markets, higher arbitrage revenues can be realised with advanced trading due to the following factors:
  - **Price granularity:** Trades can be optimised based on order book prices instead of 15-minute average intraday prices.
  - **Continuous trading:** Batteries can continuously optimise their position through continuous trading of 15-minute products on the Intraday market through virtual cycling.

Economics for example new-built battery entering 2023 (2h duration)<sup>1</sup>  
Net Present Value €/kW



1) Assuming a lifetime of 15 years or 8,500 cycles, on average 1.5-2 cycles per day. 2) Discounted revenues based on optimisation between the Day Ahead, Intraday, FCR and aFRR market

1

In Germany, wholesale markets and ancillary services are the key sources of revenues for batteries. The optimal combination of revenue streams depends on market price levels and battery characteristics.

2

Aurora models wholesale and ancillary markets fundamentally and applies a benchmark trading algorithm to evaluate business cases.

3

In 2021, a standard battery (10MW, 20MWh) could have made 160kEUR/MW optimizing over all markets. More revenues could be secured by shifting trading more towards wholesale arbitrage.

4

In the future, revenues from all markets can be expected to decrease due to market saturation and lower price levels. Energy arbitrage on wholesale markets will gain relative importance.

5

The higher fluctuations on the Intraday Market, the more important advanced trading strategies become. Algorithmic trading can help securing higher arbitrage revenues.