AURORA ENERGY RESEARCH

Battery investment cases in Germany, the Netherlands and Belgium

March 2023

The insights presented today were developed in a 9 month study in cooperation with key industry players

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Access detailed power market analysis and investment case data for batteries with our German, Dutch and Belgian Flexible Energy Market Service

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Flexible Energy Market Service

Forecast Reports & Data

Technology and Market Development Reports

- Overview of regulatory framework for batteries
- Revenue stacking models for batteries
- Projections for battery CAPEX and OPEX by delivery year
- Reports and datasets follow the same format with content tailored to specific markets

Forecast Data

- Central case forecast prices provided at hourly granularity until 2050:
  - Wholesale power prices
  - Balancing market prices
  - Intraday, FCR and aFRR market prices

Investment Cases

Standalone battery

- Multiple investment cases per country or zone including:
  - Arbitrage of wholesale market and balancing market
  - Focused participation in frequency control market (if applicable)
- Annual project margins to 2050; IRR and NPV for multiple entry years

For questions or inquiries, please contact Benjamin La Trobe (Benjamin.Latrobe@auroraer.com)

Debt providers in our network agreed to act as a reference on Aurora's bankability

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References from lenders (contact details available on request)

- Paul Batelle, Director Infrastructure and Energy Finance
- Thomas Honig, Director Infrastructure and Energy Finance
- Dominik Franz, Senior Project Manager
- Antje Gruber, Senior Project Manager
- Tim Koenemann, Global Head of Coverage Renewable Energies
- Eckhardt Doose, Vice President Renewable Energy Project Finance
- Jörg Uwe Fischer, Head of Department New Energies
- Thomas Benz, Deputy Head of Department Financing Energy & Infrastructure Financing
- Katharina Stahl, Senior Originator Project Finance
- Dimitris Skordilis, Director Infrastructure & Power Project Finance
- Christoph Tomas, Head of Project & Infrastructure Finance
- Markus Schröder, Deputy Head of Structured Finance for EMEA, Germany
- Peter Schäfer, Director, Team Head Wind Power
- Caroline Lytton , Managing Director, Head of Power & Renewables
- Yuko Misu, Associate at DBJ

"We consider Aurora to be the most thoughtful and forward thinking of the market advisers across the European power markets we look at. We value their added insight into emerging trends and the work they put into making their message easier to understand and translate to our key stakeholders.

Amongst the advisers we work with their market forecasts and scenario are seen as very credible with our internal credit teams and with investors who we work with."

***Paul Batelle**, Deutsche Bank*

Source: Aurora Energy Research

Agenda

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I. Why flexibility and batteries are important

II. Auroras methodology for modelling battery business cases

III. Battery Outlook in Germany, the Netherlands and Belgium

Rising flexibility needs and corresponding battery storage buildout is primarily driven by decarbonisation and its underlying drivers

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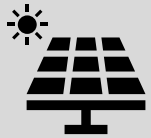
Decarbonisation drivers

1. **Variable renewables (RES) deployment**



2. **Thermal generation phase-out**

3. **Electrification of other sectors**[1]

Effects on power markets and battery storage requirements

Energy markets (wholesale)

- Merit order effect: Low marginal cost techs pushing average prices down – capture prices for RES assets increasingly decoupled from commodity prices
- Increases the intermittency of energy generation (increasingly reliant on weather patterns) leading to an increase in price volatility

Battery storage complements intermittency of renewables and balances baseload prices by charging in periods of high RES production and discharging in peak periods

Capacity Markets

- Thermal retirement and non-firm RES contribute to drop in firm capacity
- Increase in peak electricity demand can also increase the need for firm capacity

Battery storage contributes to availability of firm capacity on the system

Balancing and Ancillary Services

- Variable renewables increase need for energy balancing and system services
- Constraint management[2] and the increasing shift from centralised to distributed generation further drives an increased need for these services
- Thermal retirement also drives a need for independent procurement of grid services

Battery storage contributes to ensuring operability of the grid

1) Growing demand could improve business case for storage if it is dumb demand; but if it is smart demand then detracts from business case for grid scale batteries. 2) Increase in constraint management is further driven by RES deployment outpacing grid capacity.

Source: Aurora Energy Research

Due to a 3.7 fold increase in intermittent renewables and 82% more demand, the need for flexibility in the system is rising

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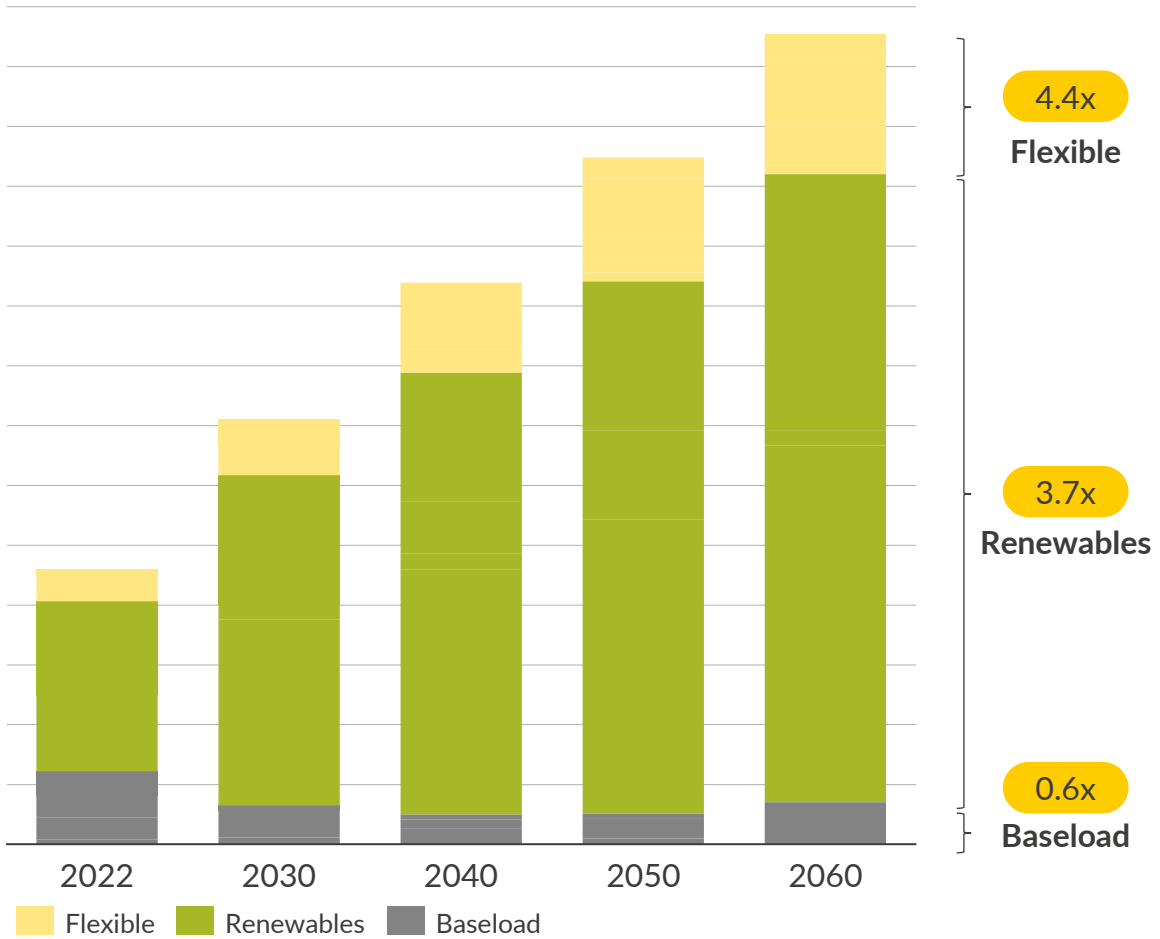
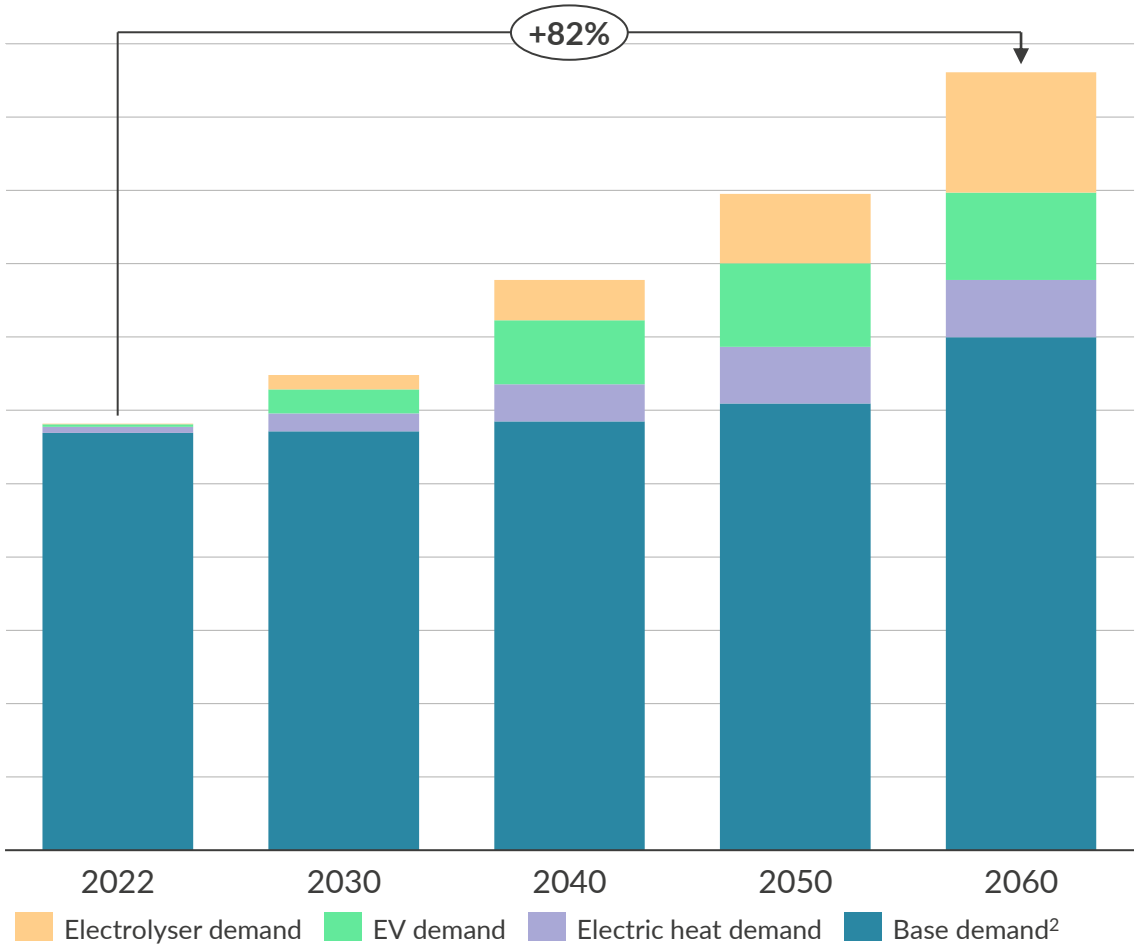
Installed capacity 1 2
GW



Net annual power demand by type – Central scenario 3
TWh



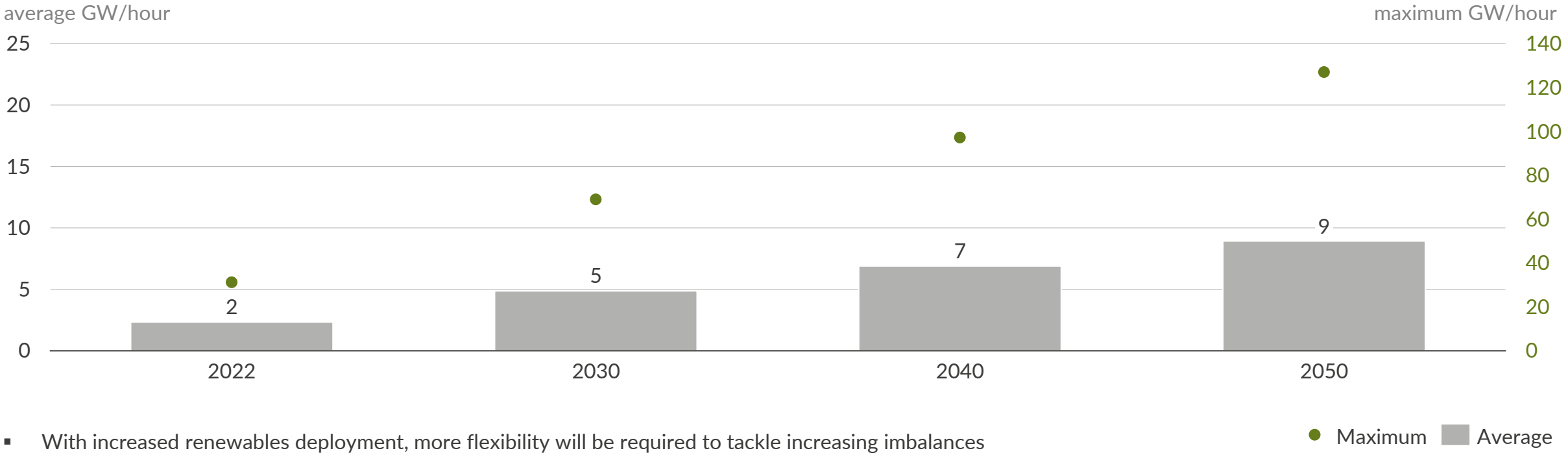
1) Total net power demand includes sectoral demand (i.e. industry, commerce, transport and households) as well as transmission losses, but excludes power plant self-consumption and demand from efficiency losses of storage. 2) Underlying base demand excluding heat pumps, EVs and electrolysis.

Source: Aurora Energy Research

The increasing share of intermittent renewables leads to a higher need for dispatchable capacity in the system

The increase in intermittent renewables will lead to more sudden changes in output, creating a need for flexible capacities

Ramping requirements in Germany[2]



- With increased renewables deployment, more flexibility will be required to tackle increasing imbalances
- This will in turn exacerbate the need for flexibility markets
- Batteries are well suited to provide the needed flexibility

1) Aurora April 2022 Central Scenario. 2) Based on the hourly variations difference of non-dispatchable renewable production.

Source: Aurora Energy Research

Battery buildout ramped up strongly in the last 8 years - the project pipeline suggests this trend will continue

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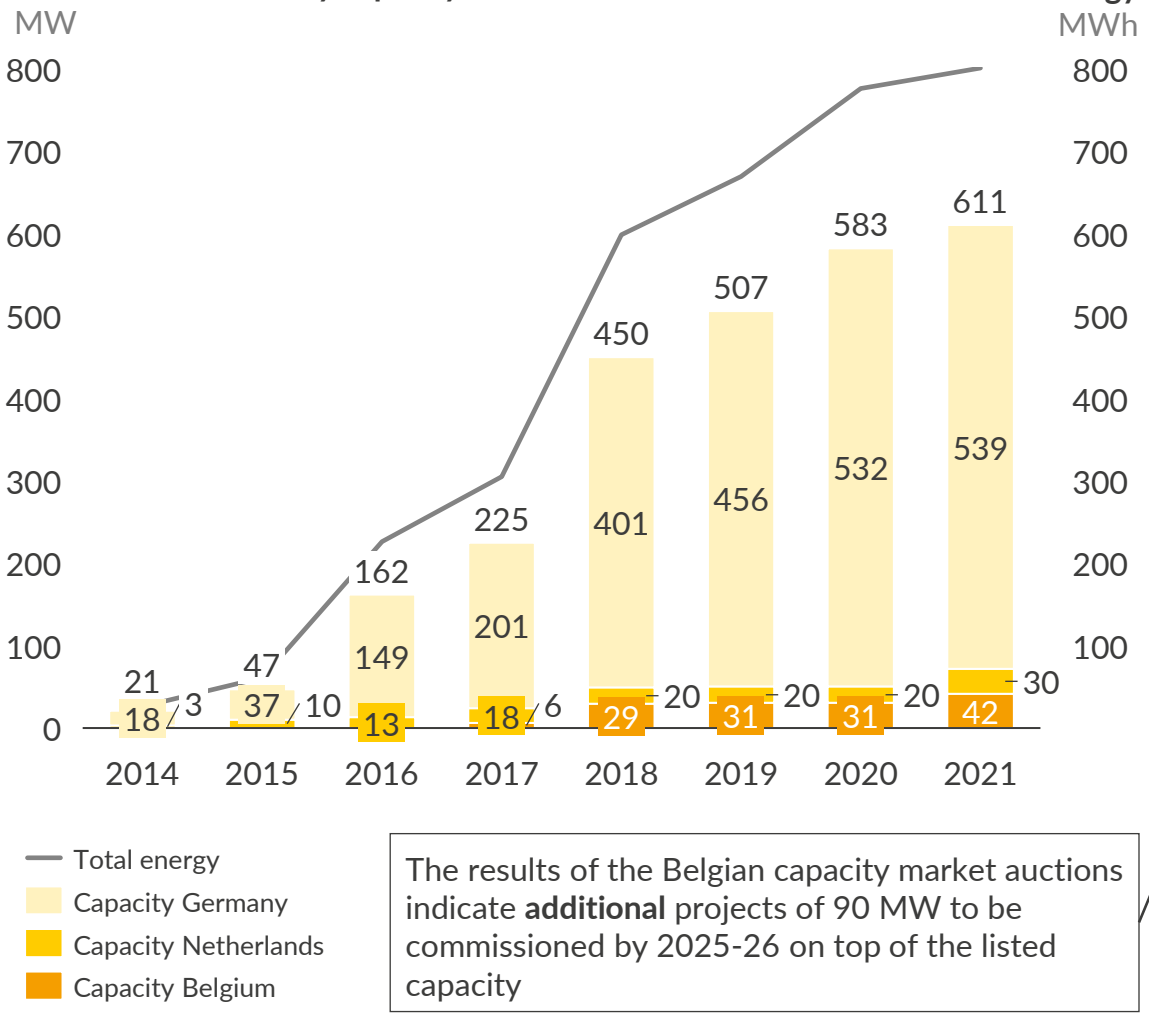
Commissioned battery capacity



The results of the Belgian capacity market auctions indicate **additional** projects of 90 MW to be commissioned by 2025-26 on top of the listed capacity

Project pipeline expected to go live in 2022/2023

Installation	Capacity (MW)	Energy (MWh)	Owner	Country
Lingen	45	n/a	RWE	DEU
Werne	72	n/a	RWE	DEU
Herdecke	n/a	4.5	RWE	DEU
Wunsiedel	100	200	Siemens[1]	DEU
Freiburg	25	n/a	JT Energy	Freiburg
Saxony	27.6	32	Berenberg	Saxony
Nyrstar's zinc smelting facility Balen	25	100	Nala Renewables	BEL
Wärtsila battery[2]	25	100	n/a	BEL
Ruien Energy Storage	25	100	Yuso	BEL
GIGA Buffalo	25	48	n/a	NLD
unknown	12	7.5	n/a	NLD
Total	**>329**	**>560**		

450 MW of grid boosters[3] will be commissioned in the next years and RWE announced severe capacity additions without mentioning single projects. More capacity is expected to be added via the German innovation auctions.

1) Together with Zukunftsenergie Nordostbayern. 2) According to Battery Industry.tech. 3) Grid boosters are battery storages that help to ensure security of supply by relieving the grid.

Source: Official announcements, Press releases, Aurora Energy Research, Bundesnetzagentur , Figgener, Jan, et al. "The development of stationary battery storage systems in Germany–status 2020.", Wärtsila

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Aurora models battery business cases in two stages based on our in-house market forecasts and imperfect foresight battery dispatch model

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Flexibility markets and battery parameters

- Day-Ahead (DA) prices
- Intraday (ID) prices
- FCR prices
- aFRR prices for capacity and energy
- Degradation, cycling rates, duration, efficiency

Imperfect foresight battery dispatch model

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)[1]
- 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

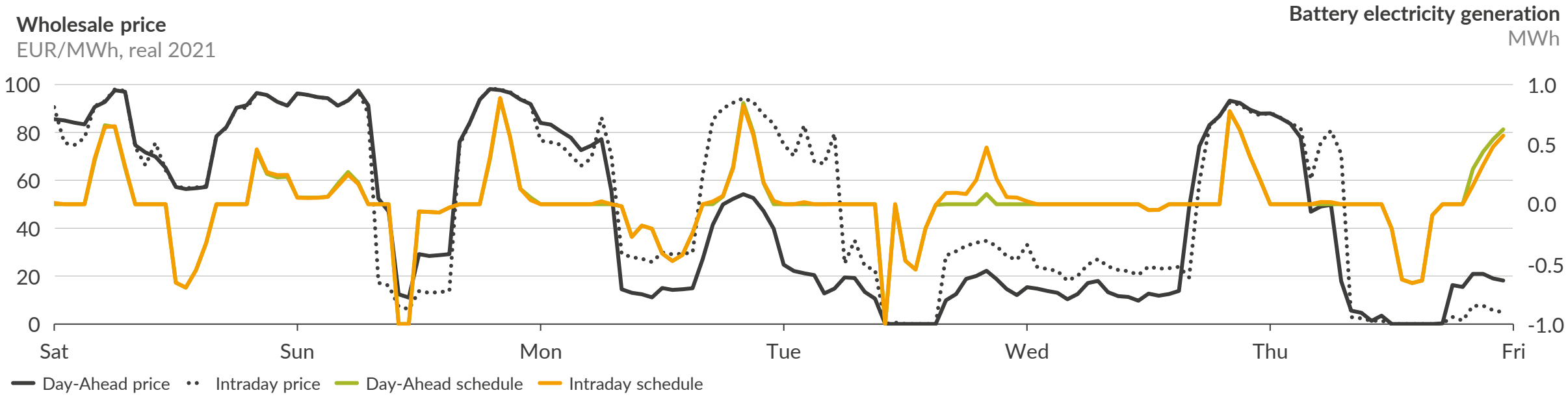
- Battery dispatch
- Revenues per market
- NPV and IRR

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.

Source: Aurora Energy Research

Balancing, wholesale and capacity markets are the key sources of revenues for batteries that optimise their dispatch based on prices

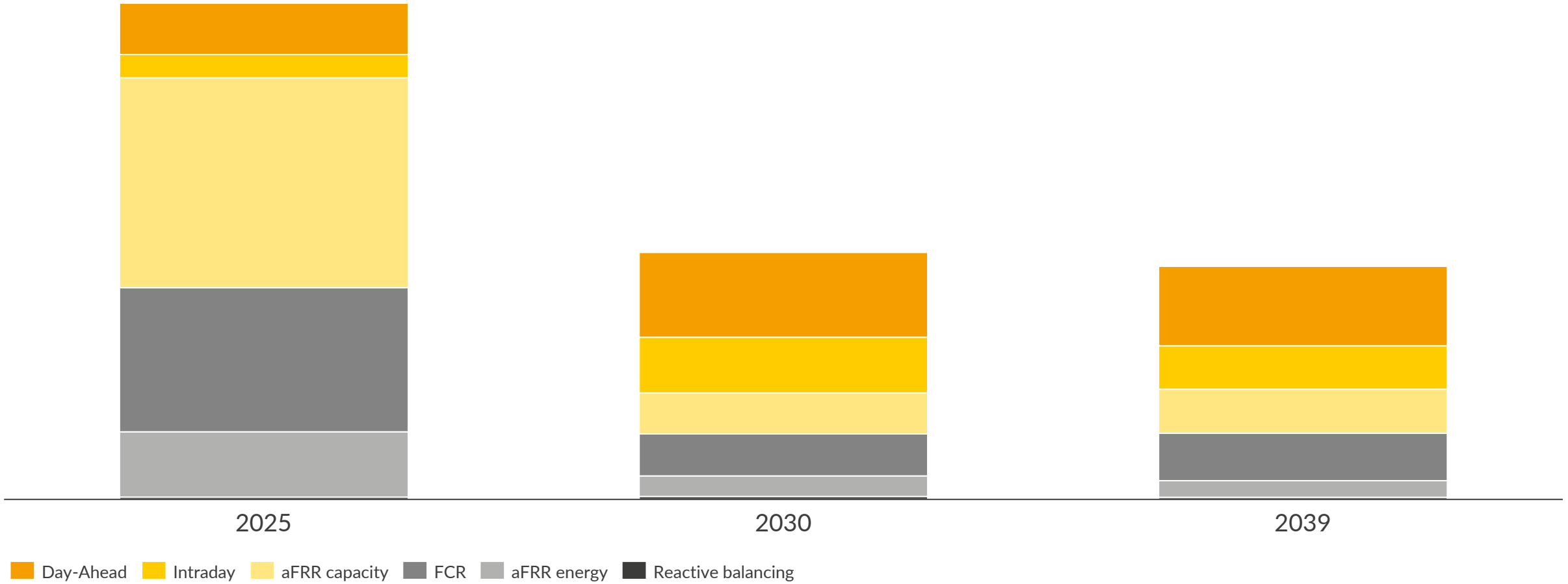
Market	Wholesale (Day-Ahead/Intraday)	Primary Reserve (FCR)	Secondary Reserve (aFRR)	Capacity Markets
Description	▪ Platform to buy and sell power to meet demand ▪ Every hour and is contracted one day before delivery (Day-Ahead) or procured continuously (Intraday)	▪ Measure to secure grid stability ▪ Flexibility providers get revenue through capacity payments	▪ Exists to ensure grid stability, gets activated after the FCR ▪ Energy will be procured via the European platform PICASSO, TSOs are in charge of procuring capacity	▪ Capacity markets reward capacity to ensure security of supply ▪ Batteries are allowed to participate with a derating factor
Revenue stream	▪ Arbitrage	▪ Capacity payment	▪ Capacity and energy payment	▪ Capacity payment



Source: Aurora Energy Research

With capacity-based balancing markets saturating towards 2030, Intraday and Day-Ahead revenues become more important

Revenues of a 2h battery, including degradation
2h battery, 2021 real EUR/kW



1) Assuming 6% WACC, 15y lifetime, 86% efficiency, 2h storage depth and 567 cycles per year.

Source: Aurora Energy Research

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Aurora's market forecasts show that batteries are bankable in Germany and Belgium, but depend on changes in grid fees in the Netherlands

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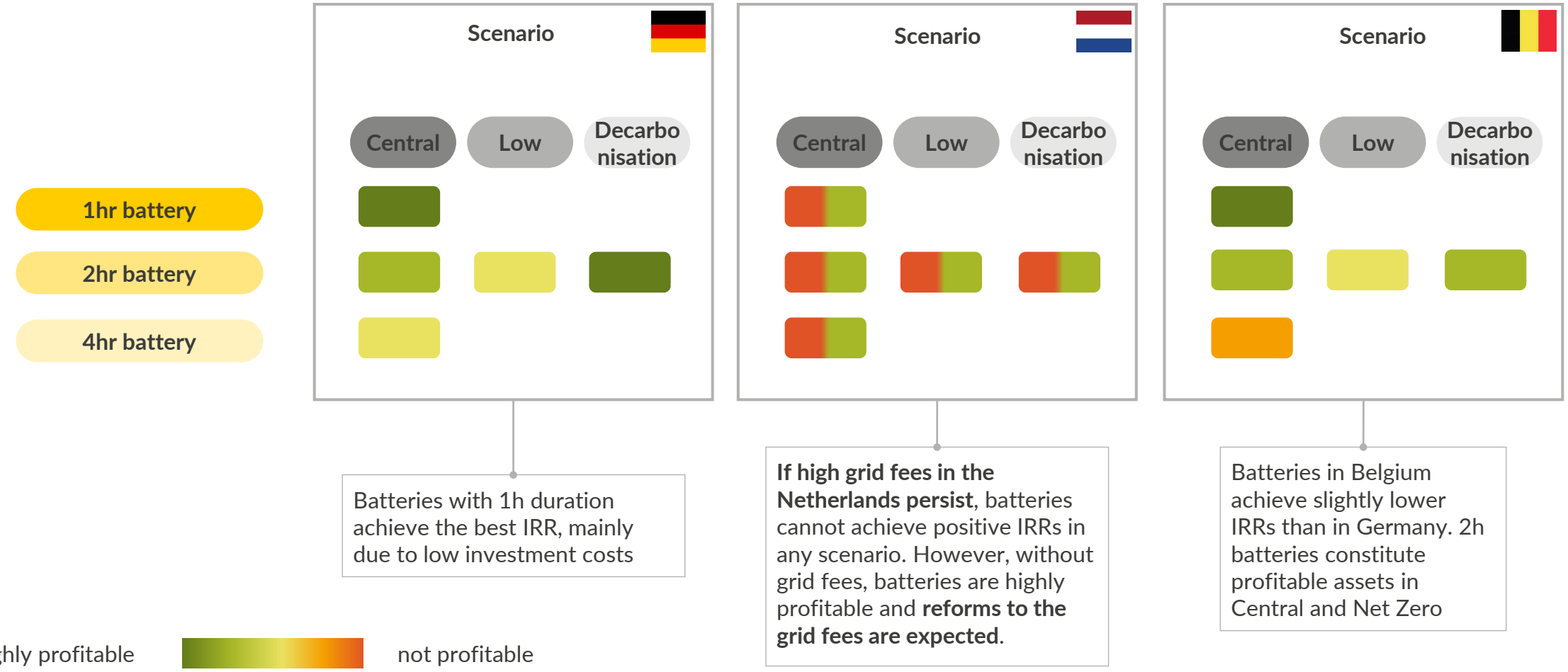
Economics for new-build battery entering the market 2025[1]
real IRR in %



Batteries with 1h duration achieve the best IRR, mainly due to low investment costs

If high grid fees in the Netherlands persist, batteries cannot achieve positive IRRs in any scenario. However, without grid fees, batteries are highly profitable and **reforms to the grid fees are expected**.

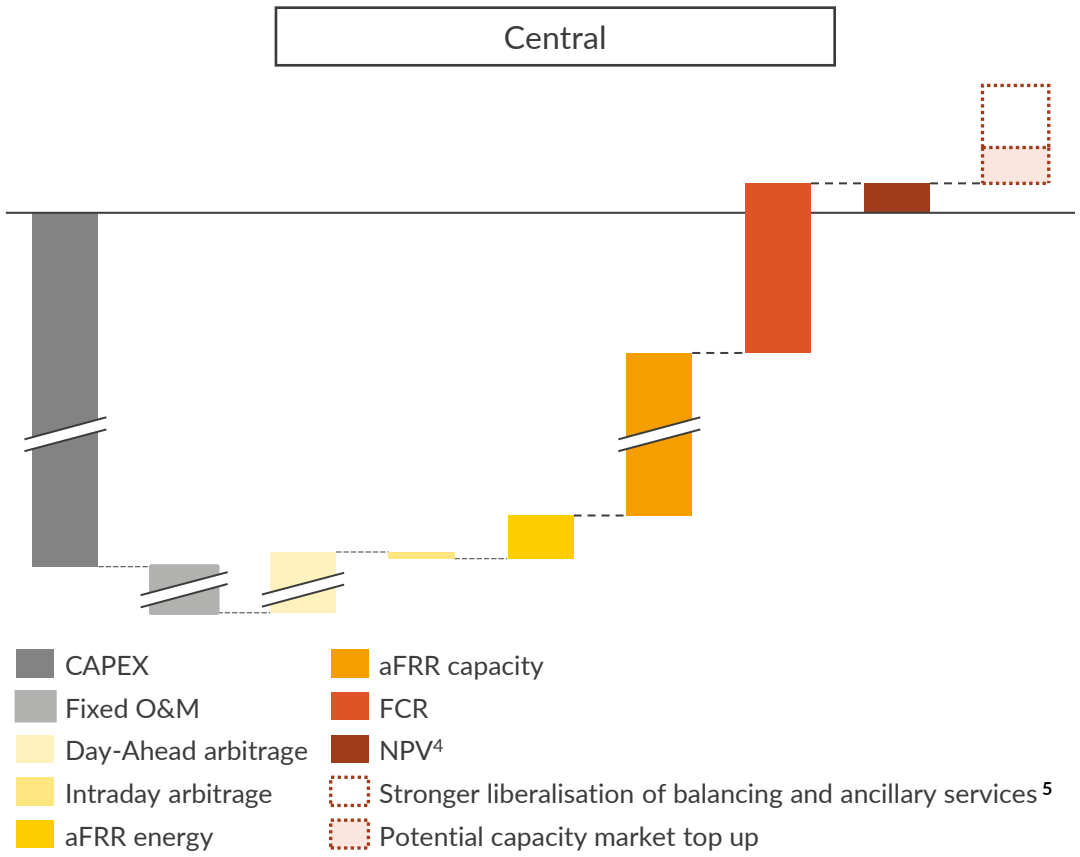
Batteries in Belgium achieve slightly lower IRRs than in Germany. 2h batteries constitute profitable assets in Central and Net Zero

1) Including grid fees.

Source: Aurora Energy Research

2h storage duration batteries are profitable in Aurora Central

Economics for example new-built battery entering 2025 (2h duration, 1 to 2 cycles/day)[1]
Net Present Value EUR/kW, real 2021



NPV[2]	Project IRR[3]	Payback Period

- Only with participating in all possible markets and doing revenue stacking, batteries can recover their investment costs
- Due to high prices on the aFRR capacity and the FCR during the mid 2020s, batteries make most of their profits on these markets
- Several upsides like capacity market payments, locational value or further liberalization of balancing and ancillary services add a premium to the already profitable business case

1) Assuming a lifetime of 15 years or 8,500 cycles. 2) NPV calculated based on discount rate of 9%. 3) IRR in real terms, i.e. to be adjusted for inflation. 4) Due to recent changes in the Energy Industry Act, battery storage is freed from levies, fees and taxes. 5) E.g. market based congestion management
Source: Aurora Energy Research

Batteries can make a positive business case through market segment optimisation, but high grid fees can turn an investment NPV-negative

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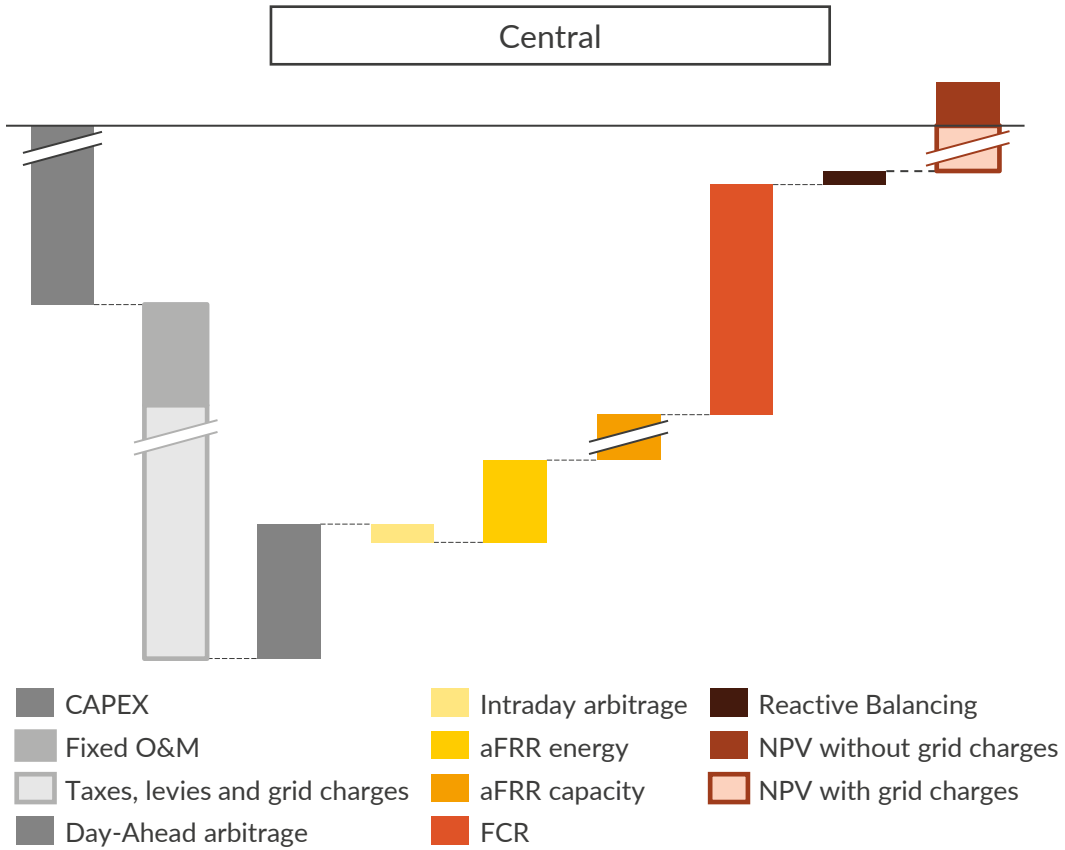
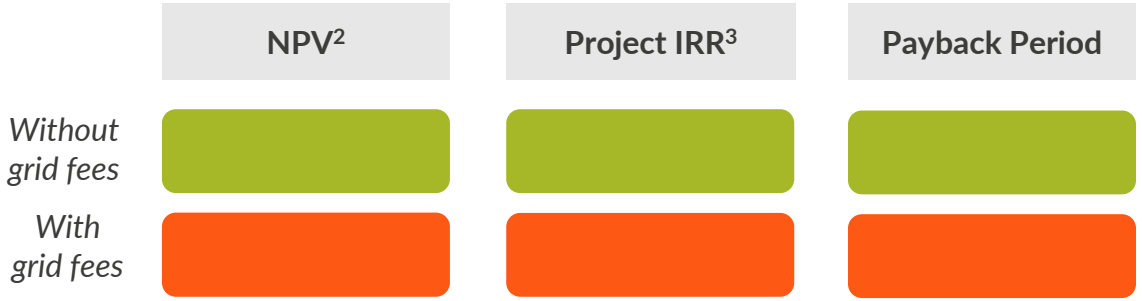
Economics for average new-build battery entering 2025 (2h duration, 1 to 2 cycles/day)[1]
Net Present Value EUR/kW, real 2021





- **Under the current high grid fee regime** for batteries, investment in the Netherland is not profitable due to the current regulatory framework, despite multiple additional revenue streams available in the Netherlands, such as
  - Locational value via GOPACS
  - Reactive balancing
- **Reforms to the height and way grid fees are applied are expected, which would lead investment to be profitable**

1) Assuming a lifetime of 15 years or 8500 cycles. 2) NPV calculated based on discount rate of 9%, without grid fees. 3) IRR in real terms, i.e. to be adjusted for inflation. 4) Batteries in the Netherlands pay a fixed grid fee per MW installed and MW peak load per month.
Source: Aurora Energy Research

To finance investments in the grid, grid fees increase from 55k EUR/MW to 84k EUR/MW in 2023

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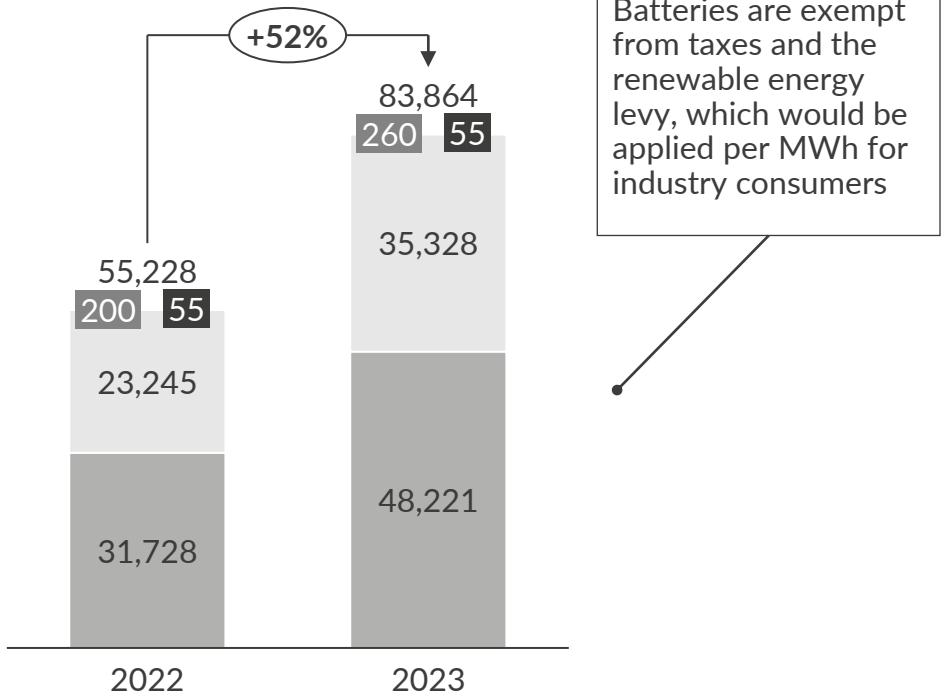
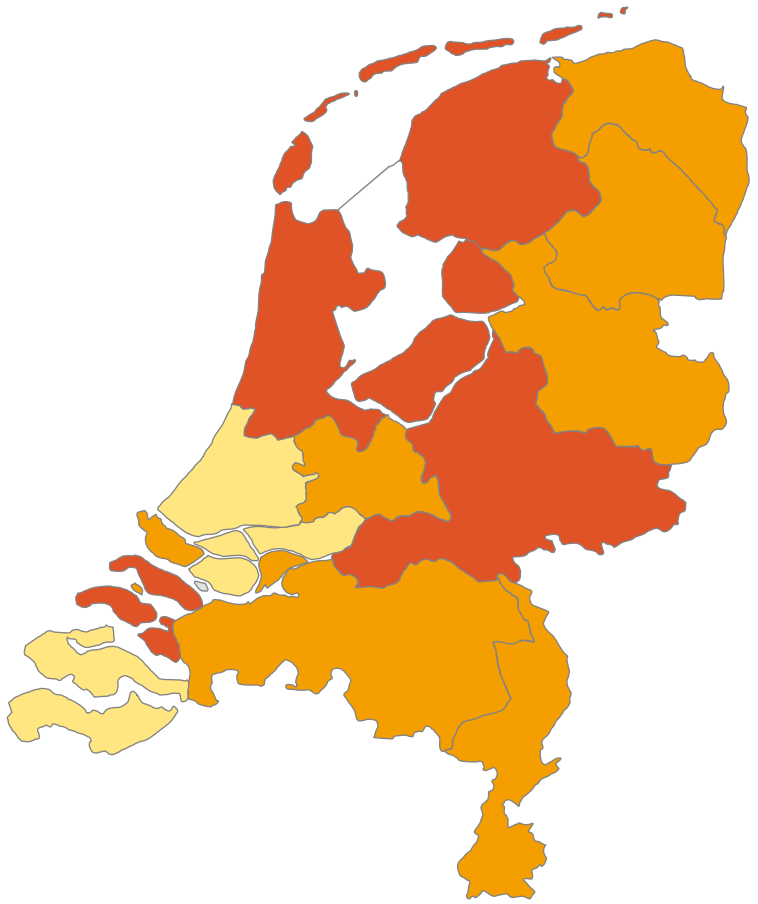
Total grid fees on a per MW basis
EUR



Total annual cost for typical[1] battery: 4,193,000 EUR/a

The Dutch Grid is heavily congested
Congestion for injecting in the Dutch grid



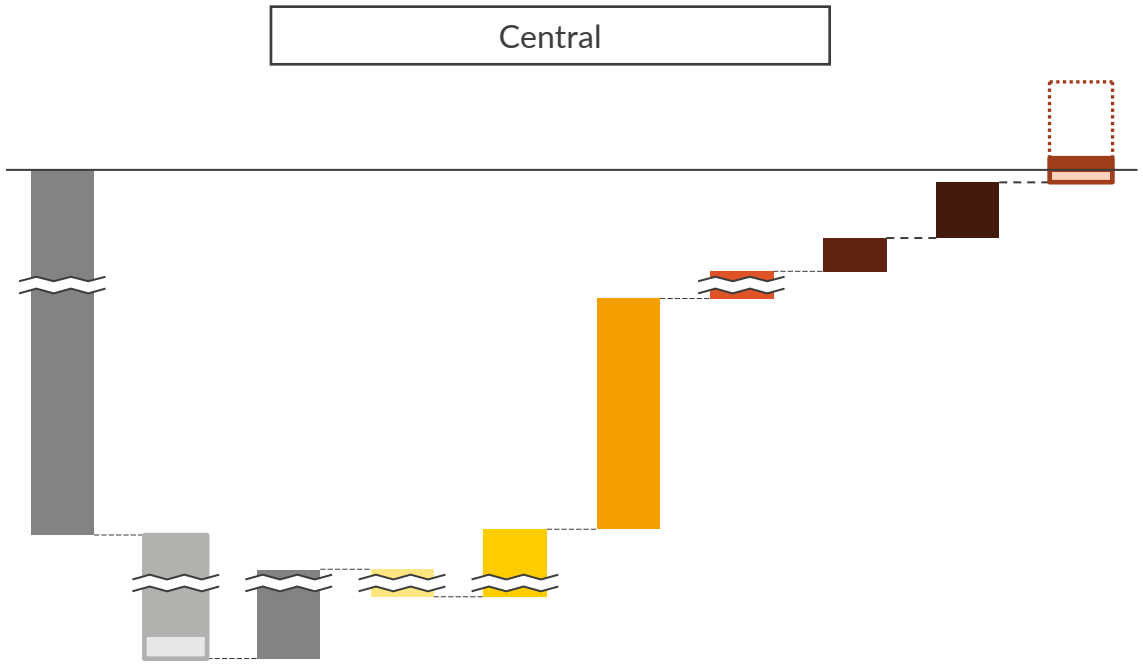
Fixed pay per connection for the typical battery (monthly)
Fixed pay per connection for the typical battery (yearly)
Per MW installed
Per MW contracted
heavy congestion
moderate congestion
low congestion

1) For the typical battery with 50 MW, 4-hour storage, 1.5 cycles per day and total energy consumption of 109.5 GWh per year.

Sources: Aurora Energy Research, Liander, Tennet

Batteries can be profitable through market segment optimisation in Belgium

Economics for average new-build battery entering 2025 (2h duration, 1 to 2 cycles/day)[1]
Net Present Value EUR/kW, real 2021



	NPV[2]	Project IRR[3]	Payback Period
With grid fees			
Without grid fees			

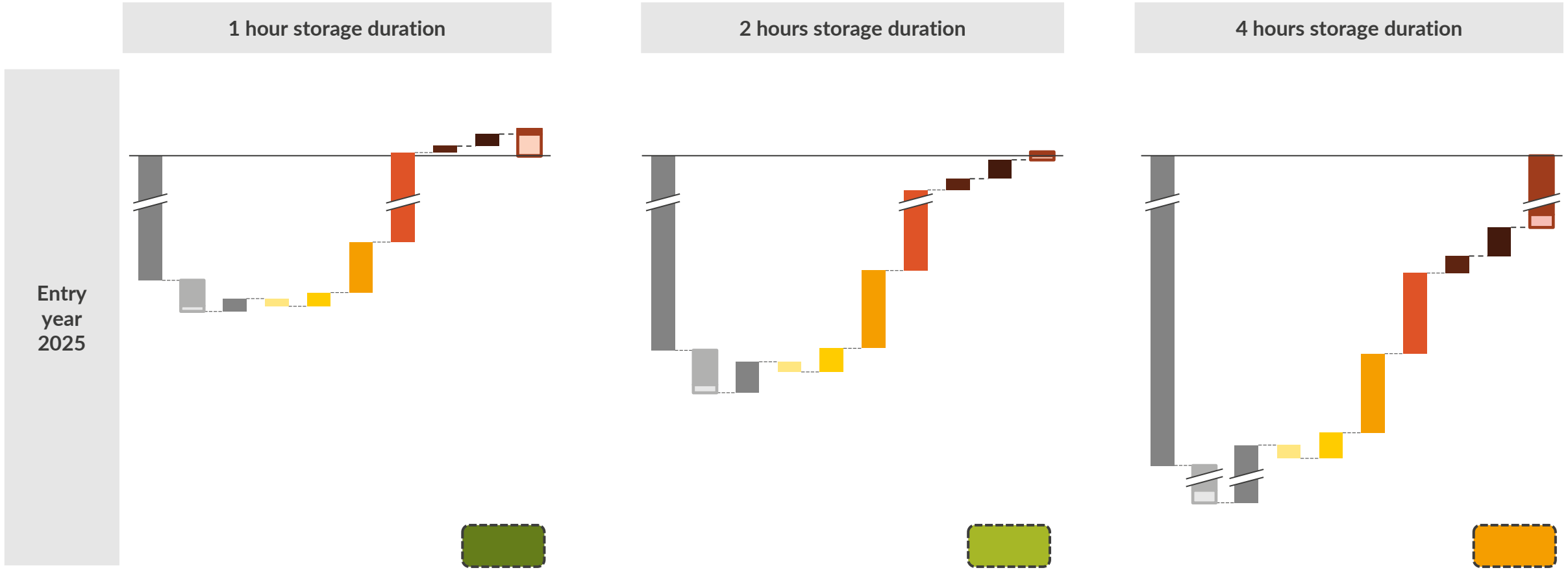
- Batteries in Belgium need to pay fees and levies, but the burden is very moderate. Hence, batteries in Belgium are profitable even if fees and taxes are applied
- An additional revenue source for Belgian batteries is the capacity market
- Revenue from locational value is not available in Belgium, but batteries can participate in reactive balancing

CAPEX
Fixed O&M
Taxes, levies and grid charges
Day-Ahead arbitrage
Intraday arbitrage
aFRR energy
aFRR capacity
FCR
Capacity market payments[4]
Reactive Balancing
Stronger liberalisation of balancing and ancillary services
NPV without taxes, levies and grid charges
NPV with taxes, levies and grid charges

1) Assuming a lifetime of 15 years or 8500 cycles. 2) NPV calculated based on discount rate of 9%. 3) IRR in real terms, i.e. to be adjusted for inflation. 4) Taxes, levies and grid charges are applied per MWh charged. 4) Payback obligation in hours with prices higher than 300 EUR/MWh is not included.
Source: Aurora Energy Research

Batteries with 1 hour storage achieve most revenues due to moderate investment costs and high FCR and aFRR capacity prices

Economics for new-build battery entering 2025 in Aurora Central
Net Present Value[1] EUR/kW (real 2021)



1) Assumed discount rate of 9% for all cash flows and a lifetime of 15 years or 8500 cycles. 2) Payback obligation in hours with prices higher than 300 EUR/MWh is not included.

Source: Aurora Energy Research

Key Takeaways

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1. Carbon free flexibility will be crucial for tomorrows power system, especially as demand rises and supply is becoming increasingly renewable and thereby more intermittent. Batteries can provide the flexibility needed.
2. The flexibility provided by batteries is needed but to be profitable batteries need to participate in all markets available and choose on an quarter hourly basis in which market they should participate to maximise their profits (market segment optimisation).
3. Germany and Belgium are very attractive markets to invest into batteries due to favourable regulation. While investments in these markets are already profitable today, additional revenue streams like a capacity market or locational value might add a premium on top of the already profitable business cases.
4. In the Netherlands, grid fees are the major road block to batteries' profitability. If the current regulation prevails, batteries will not be profitable. However, the Authority for Consumers and Markets is already aware of the problem. Given the high congestion of the Dutch grid and batteries potential to help solving this issue, it is likely that grid fees will be reformed.
5. Currently, shorter duration batteries are more profitable as increased investment costs have the most severe effect on longer storage duration batteries.

European Battery Markets Report: Assisting you with initial market scanning to identify the most attractive markets in Europe

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Available March 2023

European Battery Market Attractiveness Report – 2nd Edition

1 European Battery Market Trends – Market Size and Opportunity
- Summary of leading developers and route to market providers
- Installed capacity and near-term BESS projects pipeline
- Forecast volumes for battery deployment by year and country
- Battery investment trends and projected investment needs

2 Policy and Regulatory Environment
- Recent trends and market developments
- Regulatory framework at European level, and summary of key national strategies, policies and regulations impacting battery build out
- Policy goals/targets for batteries at European level and at national level
- Subsidies/incentives available to encourage battery build out
- Effect of cross-border trading (e.g. PICASSO, Western Europe FCR coupling, including timing of price convergence)

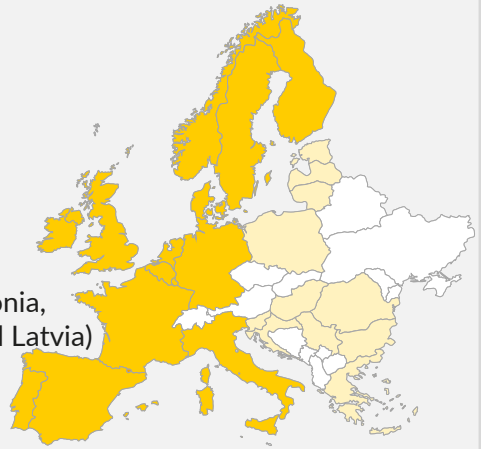
3 Battery Storage Business Models and Value Drivers
- Summary of attainable markets and revenue stacking opportunities by country, battery eligibility and barriers to entry
- Comparison of value drivers across markets, e.g.
  - RES penetration and daily wholesale market spreads
  - Balancing mechanism and services
  - Volume requirements and prices in ancillary services
  - Capacity market auctions (and quantity of capacity auctioned)
- Summary of investment-related opportunities and risks

4 Battery Economics and Business Cases (for selected countries)[1]
- Description of relevant battery business models (trading, ancillary, hybrid, co-location)
- Revenue stacking opportunities and gross margins (1, 2 and 4 hours)
- Investment cases (estimated IRRs) for energy arbitrage and ancillary services-led business models

Analysis covers 24 European markets

Full scope incl. 4
- **Great Britain***
- **Ireland (I-SEM)***
- **France***
- **Belgium***
- **Netherlands***
- **Germany***
- **Nordics*** (Denmark, Finland, Norway, Sweden)
- **Iberia*** (Portugal, Spain)
- **Italy***
- **Poland**
- **Greece**

Scope 1 - 3
- **Hungary**
- **Romania**
- **Bulgaria**
- **Serbia**
- **Slovenia**
- **Croatia**
- **Baltics** (Estonia, Lithuania and Latvia)



For markets (*) Flexible Energy subscription with detailed forecasts & business case analysis available

1. High level battery economics (estimated IRR) provided – for all denoted markets (*) Aurora offers a Flexible Energy subscription service with detailed revenue stream forecasts and battery investment case analysis

Source: Aurora Energy Research

Subscribe to powerful forecast and data services for tailored research in market developments, policy interpretation, and topical energy market issues

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Power and Renewables Service

Robust, transparent analysis, widely used and trusted amongst the major market participants

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Detailed analysis and granular forecasts for power, balancing, and ancillary service markets, plus investment case data for a wide range of battery storage and gas peaker business models

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Dedicated insights following policy developments and project activities across power, heat, transport, and industry

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ORIGIN
Putting Aurora's power market model into your hands

AMUN
Quantifying the true value of your wind project in minutes

CHRONOS
The leading battery analytics software

RA
Solar market software
(coming soon)

EOS Subscriber Platform

AURORA EOS

Report & Forecast Dataset Library | Historical Data Dashboard | Forecast Scenario Explorer | Software

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