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From Volatility to Value: Negative Prices and Batteries in the Baltics

Public Webinar 4th of June 2025

Introducing the speakers

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Agenda

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I. Introduction to Aurora

II. Price volatility and negative prices

III. Opportunities for batteries

IV. Conclusions and next steps

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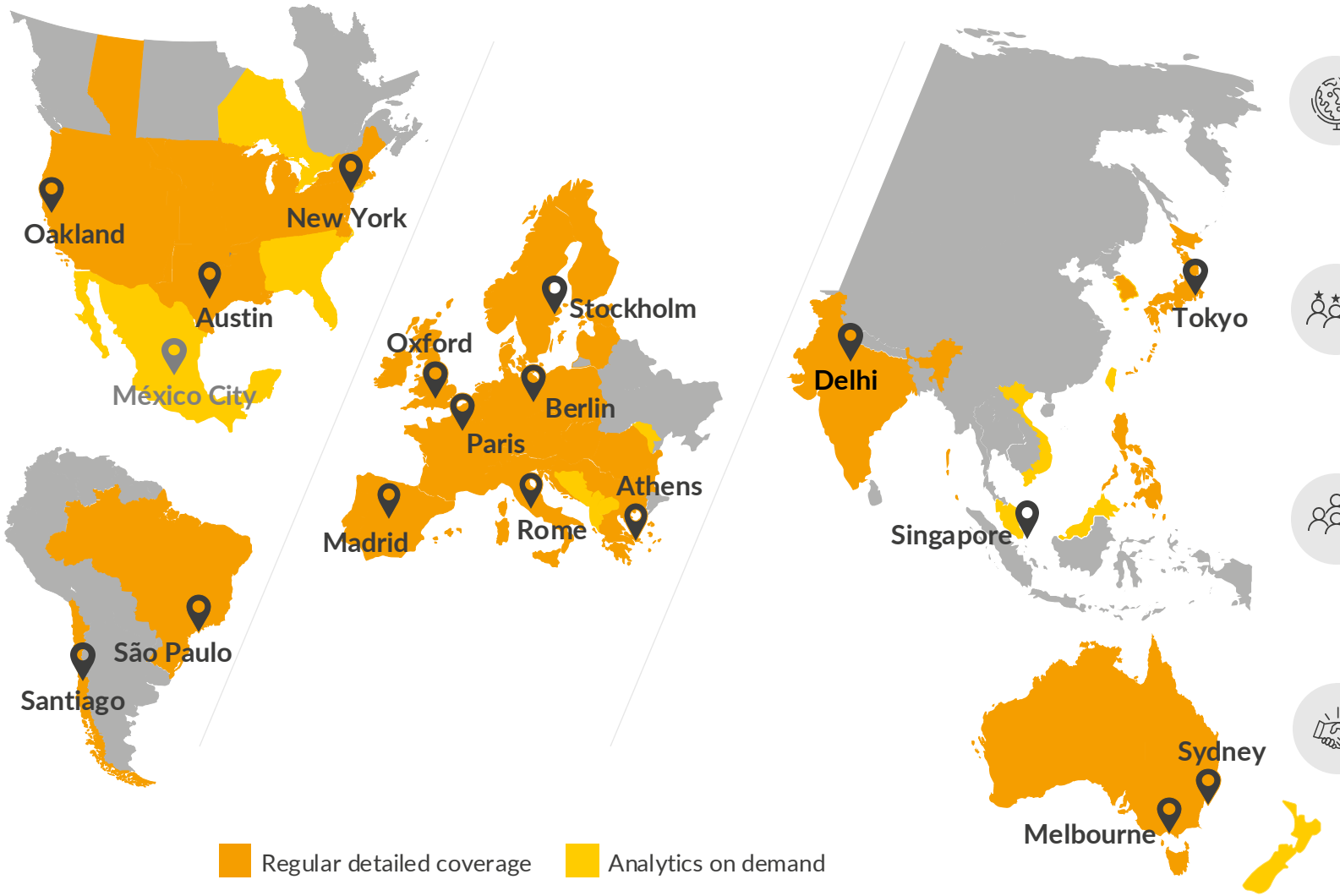
- Power markets
- Renewables & PPAs
- Storage
- Grid & Congestion
- Electric vehicles
- Hydrogen H_2
- Carbon CO_2
- Natural gas



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transactions supported in 2024

Source: Aurora Energy Research

Our market leading models underpin a comprehensive range of seamlessly integrated services to best suit your needs

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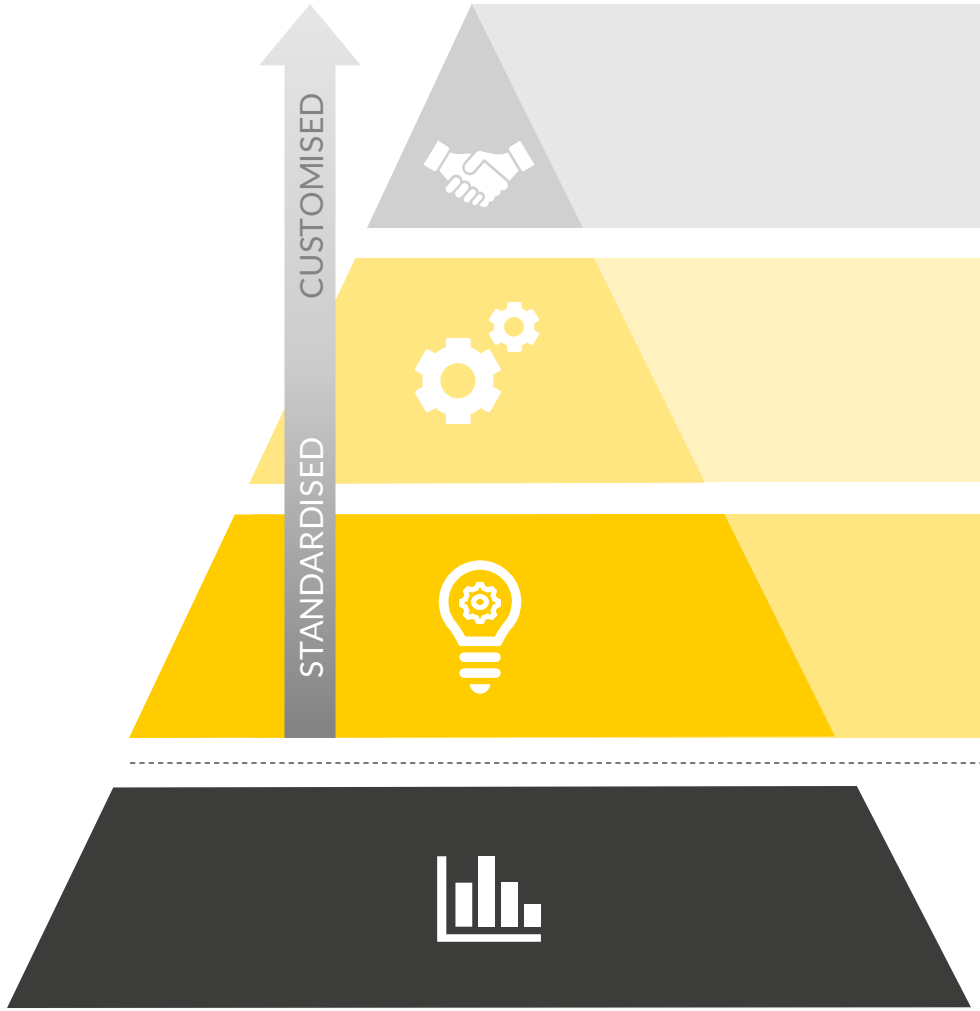

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Source: Aurora Energy Research

Rapid wind and solar expansion along with modest demand growth strongly reduces the Baltics' reliance on fossil generation and imports

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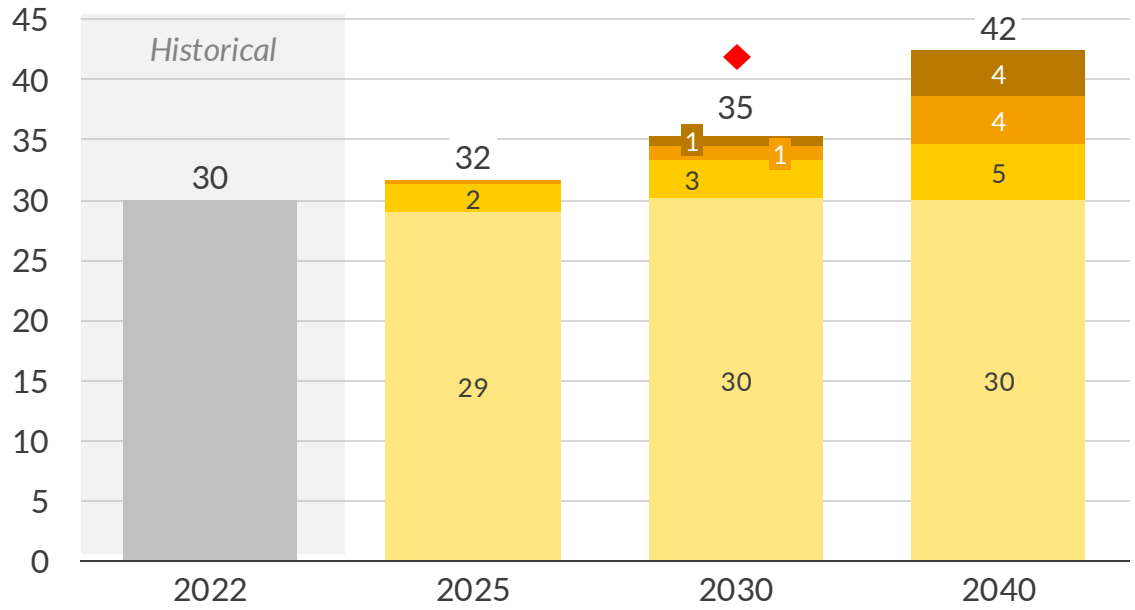
Electricity demand in the Baltics

TWh

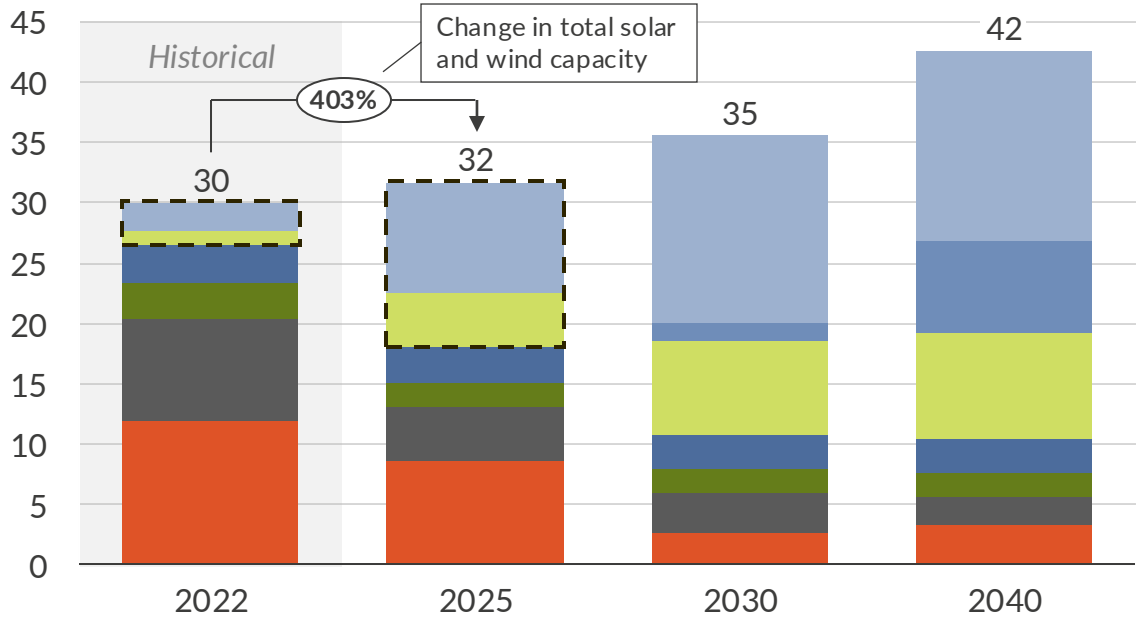


- Power demand in the Baltics has remained relatively flat in recent years, with additional demand from emerging sectors largely offset by improved efficiency and weak economic growth.
- Post-2030, demand growth is driven by electrolysers, EVs and heat pumps, while base demand falls due to energy efficiency gains and population decline.

Historical demand | Electric Heating | Hydrogen | Base demand | Electric vehicles | TSO estimate[1]

Electricity generation and net imports in the Baltics

TWh



- Wind and solar generation is set to reach four times 2022 levels this year, with further growth making intermittent renewables the dominant generation technology by the 2030s.
- While net imports decline drastically by 2030, the Baltics remain a net-importing region due to weak capacity growth in the 2030s.

Onshore wind | Solar PV | Biomass | Interconnectors | Offshore wind | Hydro | Fossil thermal

1) The sum of central scenario estimates for 2030 demand by the TSOs, methodologies and definitions may vary.

Sources: Aurora Energy Research, Ember Climate, Elering, Litgrid, AST

The number of negative price hours in the Baltics has risen sharply in just two years but remains far below Nordic levels

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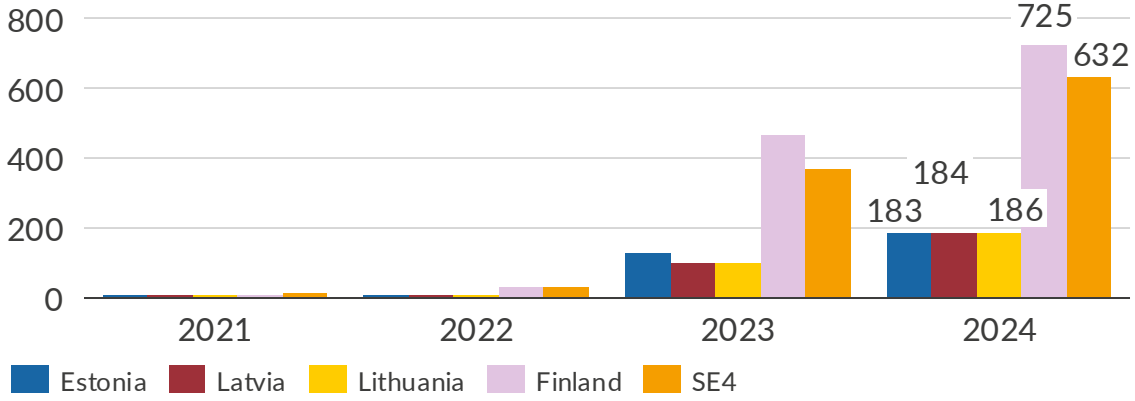
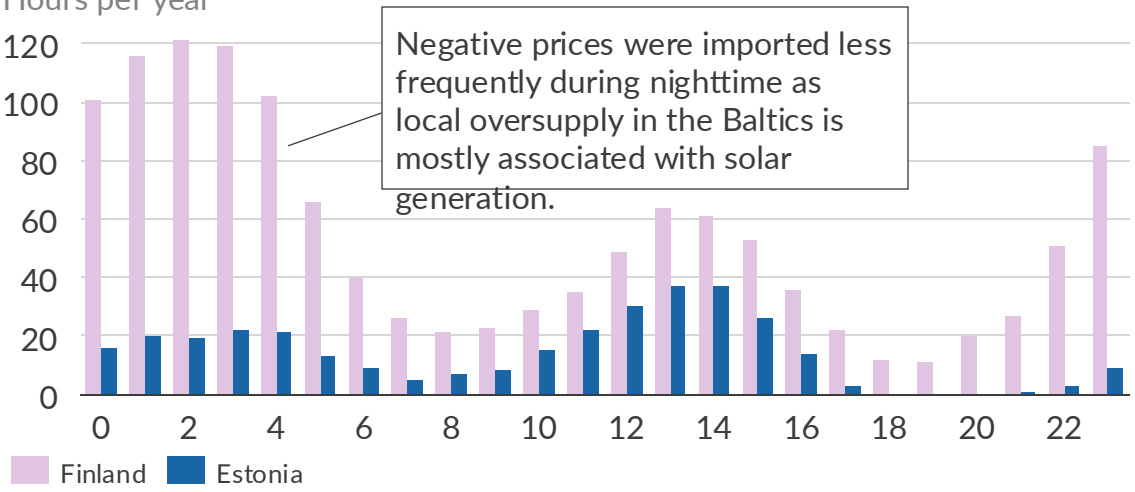
Historical negative price hours in the Day-Ahead market

Hours per year



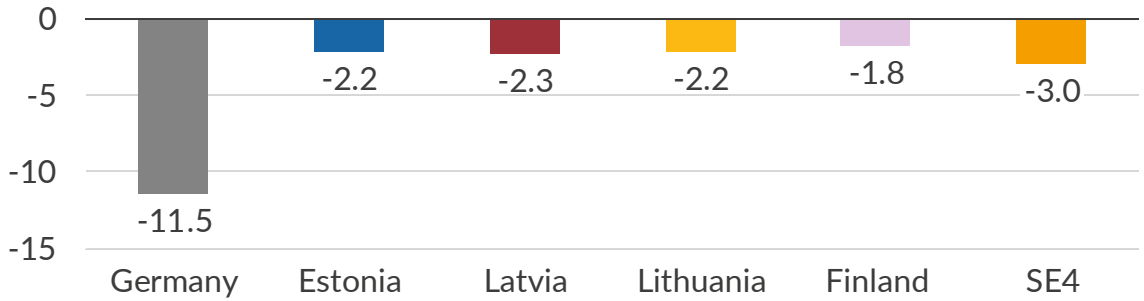
Historical negative price hours by the hour of the day in 2024

Hours per year



Average depth of negative prices in the Day-Ahead market in 2024

€/MWh (nominal)



Drivers for negative prices in the Baltics

- Negative power prices in the Baltics are almost exclusively imported from the Nordics, where the number of negative price hours is markedly higher.
- While the Baltic negative prices have been on average deeper than the Finnish ones, the negative prices in the Baltics and neighbouring Nordic regions remain shallow compared to continental Europe, e.g. Germany.
- Drivers of negative prices include:
  - Lack of incentives for assets to curtail generation during negative price hours due to subsidies, GOs[1], missing price signals, or high costs of ramping production up and down.
  - Lack of technical ability to curtail, e.g. with rooftop solar.
- Most of the existing demand is not flexible enough or does not face price signals to shift offtake to these hours, contributing to the power oversupply.

1) Guarantees of Origin.

Sources: Aurora Energy Research; Nord Pool

After the surge in recent years, the number of negative price hours, driven by renewable oversupply, decreases towards 2035 due to rising system flexibility

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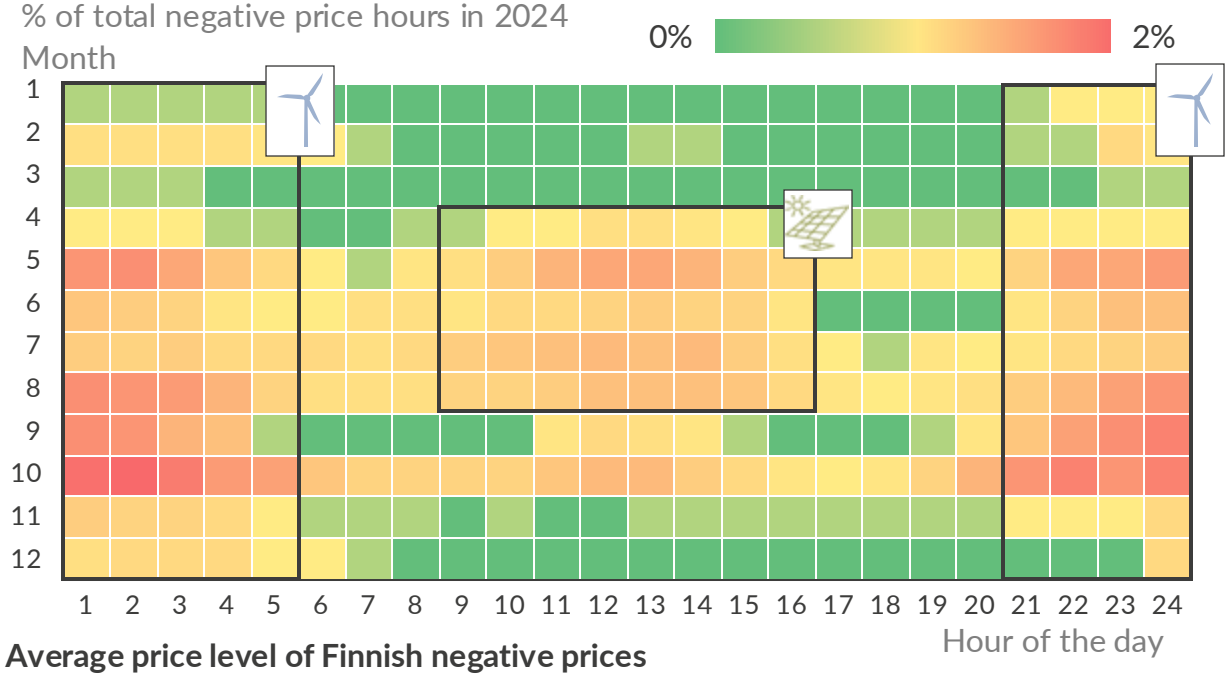
Share of negative prices in Finland by hour of the day and month

% of total negative price hours in 2024



Average price level of Finnish negative prices

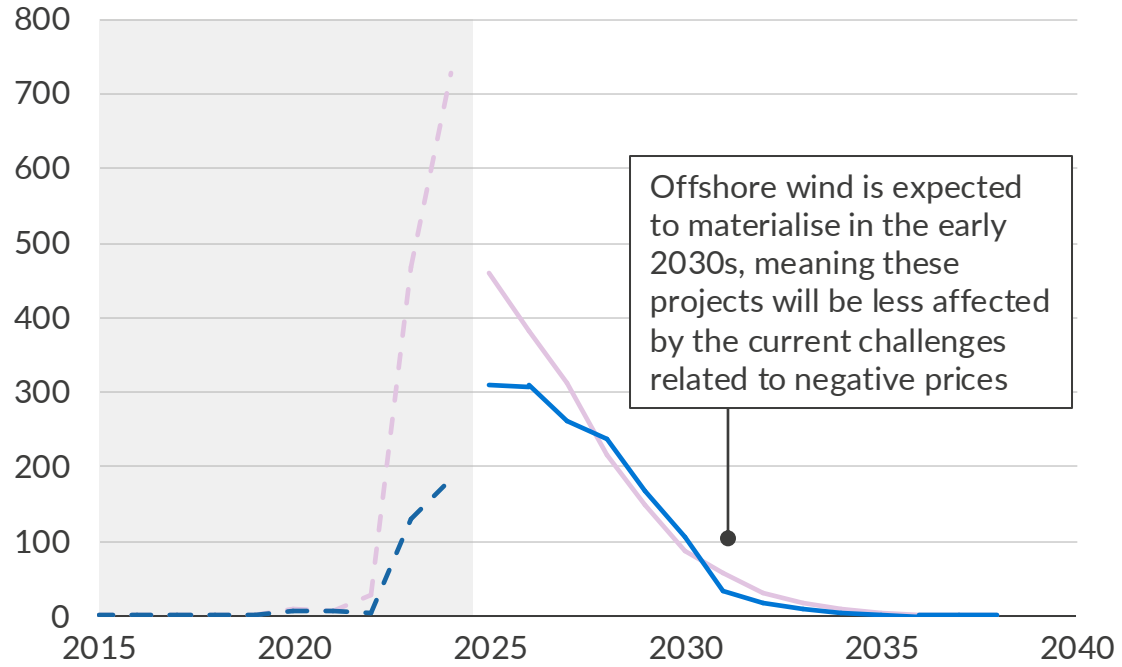
€/MWh (nominal)

-1.3 Close-to-zero negative prices typically occur during nighttime and morning hours, driven by negative bids from wind and inflexible hydro assets in Finland and Sweden.

-3.0 Negative prices tend to be deeper during sunny hours, driven by imports from Germany and the Netherlands.

Total number of negative price hours[2]

Hours p.a.



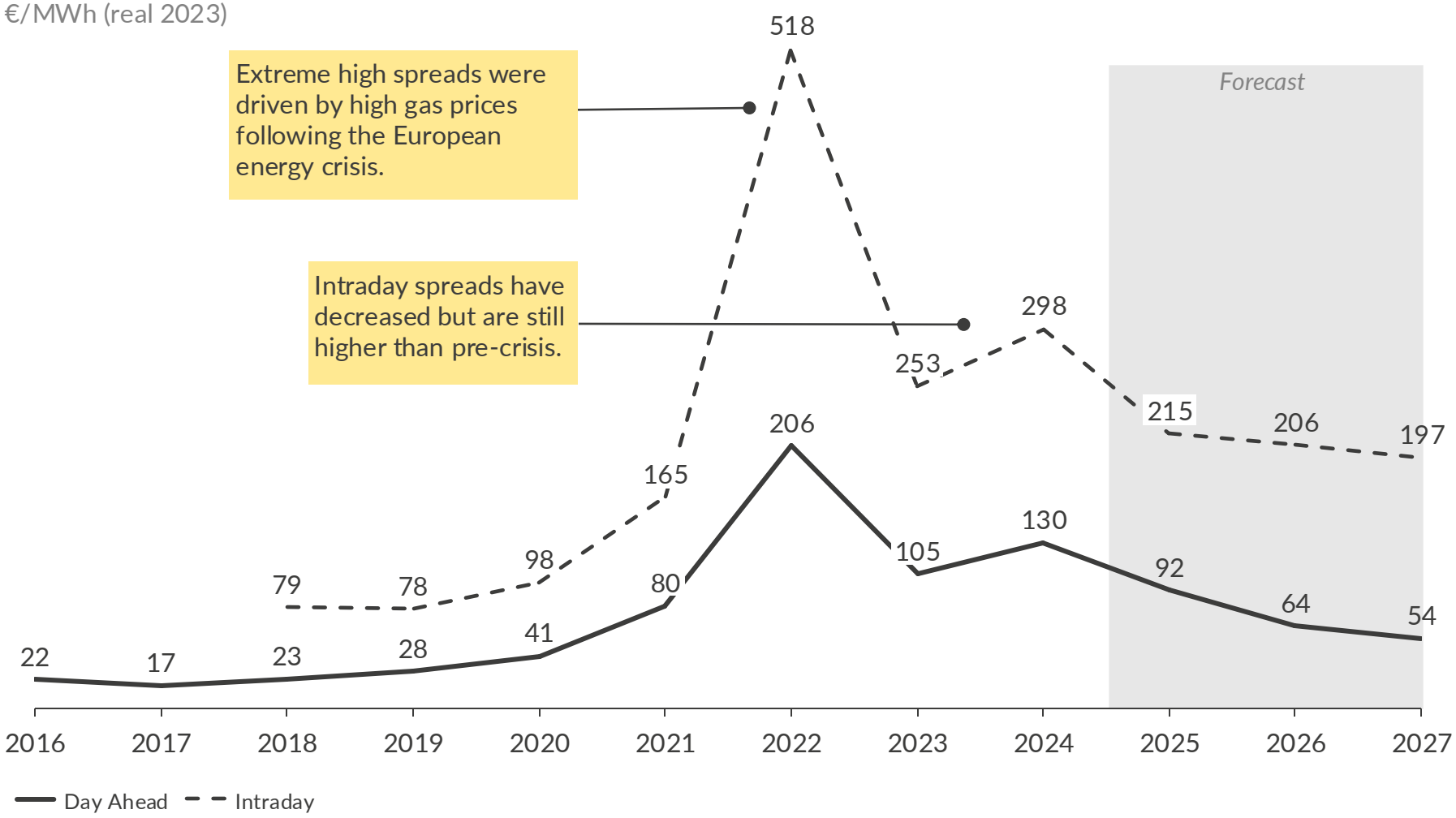
- We expect negative price hours to decline from 2028 and disappear after 2035. Growing flexible demand technologies, like EVs, electric boilers, and electrolysers, reduce the frequency and depth of negative prices.
- At the same time renewables become more responsive to price signals as PPAs and subsidy schemes in neighbouring countries align with market conditions.

1) Aurora Central scenario, April 2025; 2) Three-year rolling average.

Sources: Aurora Energy Research, Nord Pool AS

Day-ahead and intraday arbitrage provide key revenue streams for batteries but cannot carry future battery investments in the Baltics

Average 2-h daily price spreads in Lithuania[1]
€/MWh (real 2023)



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Project economics – Stacked revenue streams

- Energy Arbitrage is the process of **buying** energy **when it is cheap** and **selling when it is expensive.**
- In the long-run **spreads** are expected to **decrease** and stabilise.
- Revenues from **Intraday** are more **uncertain**.
- Day ahead and intraday arbitrage alone **is not sufficient** to carry future battery investment in Baltics.

Various forms of flexibility are needed, and batteries can play a key role in ancillary markets, generating revenue while enhancing system stability

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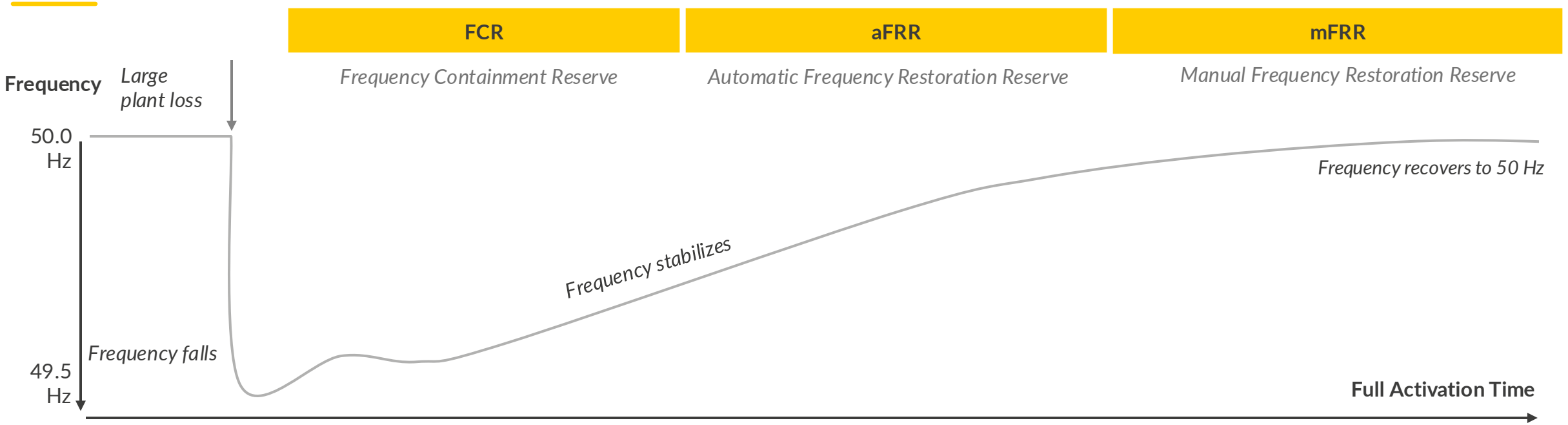

	<30 seconds	<5 minutes	<12.5 minutes
Volume required, Baltic block	36 MW	90-120 MW up and down	600–770 MW up 370–610 MW down
Battery suitability	High ↑	Medium, →	Low, ↓
Saturation risk, >3yy	High risk ↓	Medium risk →	Low risk ↑
Relevance for Baltic BESS	Very short term	Medium term	Medium to long term

Sources: Aurora Energy Research; ENTSO-E; Litgrid

Value stacking across energy arbitrage and ancillary capacity payments reduce the revenue risk from market saturation.

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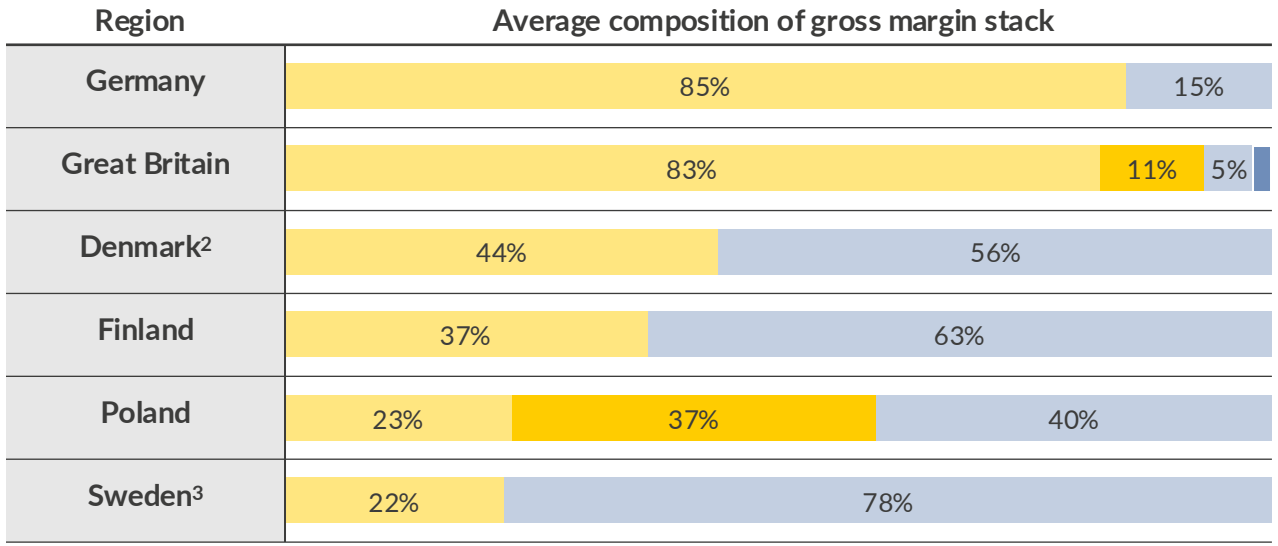
Summary of gross margin stack market composition[1]
% of 2028 – 2042, 2h duration batteries



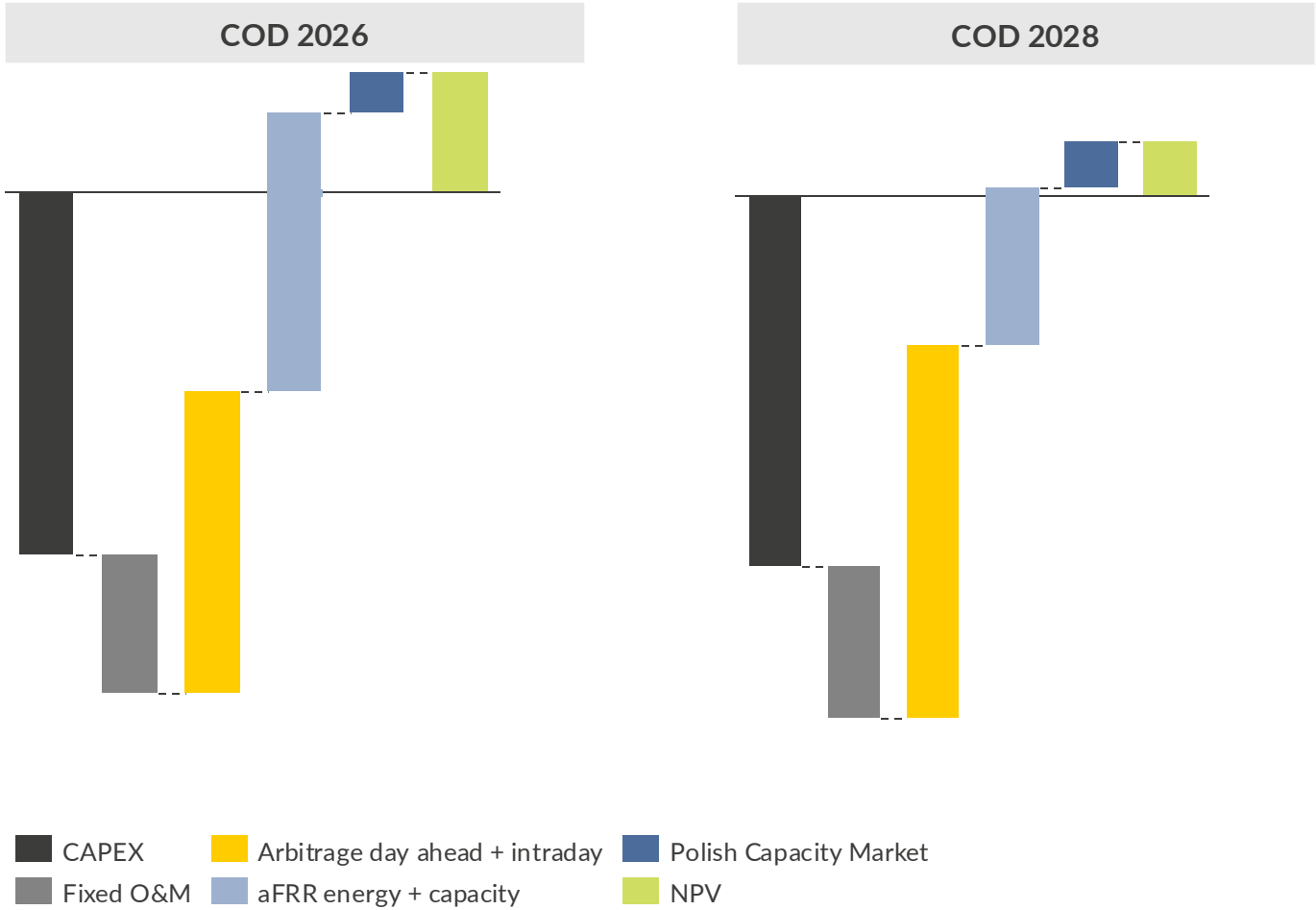
- Day-ahead and intraday **arbitrage alone is not sufficient** to carry future battery investment due to decreasing volatility.
- Capacity remunerated ancillary markets are small and risk **saturation in the long run.**
- **Mature battery markets** such as Great Britain and Germany where frequency services are already saturated **depend more on arbitrage revenues.**

1) Discounted with 11%. 2) Represents DK2. 3) Represents SE4. 4) Includes Balancing Mechanisms in GB and Ireland and slower frequency products with full activation time > 10 min such as mFRR. 5) Includes Triads and GDUoS benefits in GB

Source: Aurora Energy Research

Batteries with later commissioning dates can expect lower returns due to risks for market saturation on ancillary markets

Economics for a 2-h battery in Lithuania
Present value[1] €/kW battery capacity (real 2024)



Key insights

- In the earlier years of operation, revenues from aFRR are most relevant, while arbitrage becomes increasingly important over time.
- **Uncertainty on future price developments** in ancillary markets favors early entrants.

Findings from case studies:

- **Higher battery duration** achieve higher revenues from energy arbitrage than shorter durations and have an **economic advantage** in Baltics.
- 2h and 4h BESS have an advantage from participating on the **Polish CM.**

1) Assumed discount rate of 11% for all cash flows and a maximum lifetime of 15 years

Source: Aurora Energy Research

Co-location provides cost savings and, depending on the configuration, can optimise revenues due to the flexibility provided by batteries

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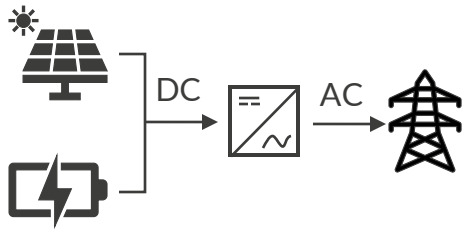
1 Co-location can provide savings for several cost components

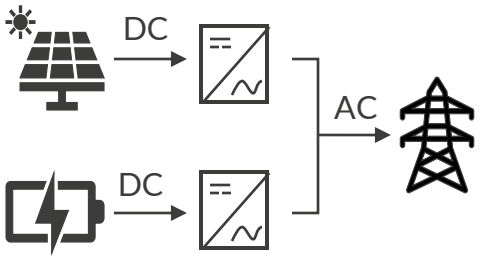
Cost components[1], EUR/kW/year

2 DC coupling can provide savings on inverter costs while AC provides more reliability

DC Direct Current coupled configuration[3]

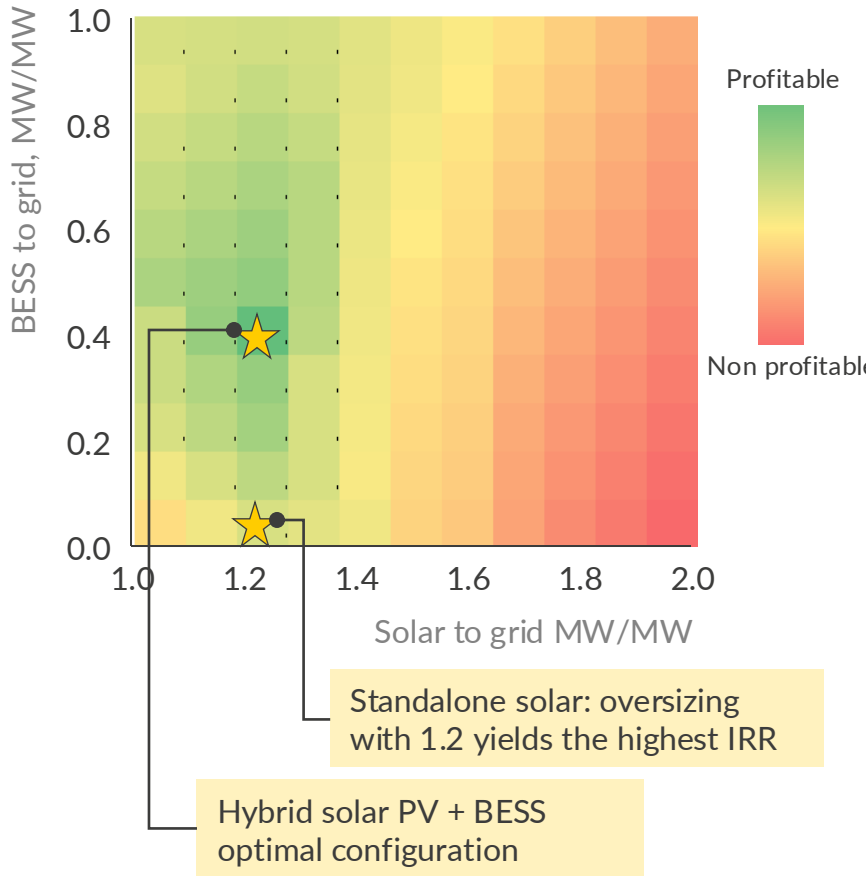


AC Alternating Current coupled configuration[4]



3 Battery dimensioning optimizes co-location revenues – dimensioning is very site-specific

IRRs, %, for BESS and solar PV dimensioning exercise



1) We consider a 10-20% saving compared to stand-alone; 2) For a solar asset this represents panels, inverter, .etc.; 3) Solar and battery share a single inverter which connects to the grid; 4) Solar and battery require separate inverters to connect to the grid. Co-located system has more reliability in the event of inverter unavailability or failure

Sources: Aurora Energy Research

Conclusions

1. The Baltic power system is undergoing a profound shift, moving towards European integration and away from fossil fuels and imports with a continued growth in onshore wind and solar PV. However. limited PPA markets and falling capture prices pose significant challenges for further renewables buildout.

2. The Baltics have experienced a sharp rise in negative power prices in recent years, mostly imported from the Nordics due to renewables oversupply and limited flexibility. As technologies like electric boilers and batteries scale up, the number of negative prices is expected to decline toward zero by the mid-2030s.

3. Price spreads in the Baltics remain above pre-crisis levels due to a mix of cheap renewables, expensive thermal generation, and cross-border price differences, offering strong—though gradually declining—opportunities for energy arbitrage. As spreads decline over time, the economics of batteries in the Baltics increasingly depends on mix of revenues from both energy arbitrage and balancing markets.

4. Battery profitability depends on the regional market's revenue stack, with arbitrage dominating in mature markets and capacity markets supplementing revenues where available. Co-locating with renewable sources can drastically improve economics when stand-alone viability falls short, especially when asset-to-grid ratios are optimised.

Baltic Power and Renewables Market Service:

Dive into key market analysis and forecasts for the Baltics power and renewables markets

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- **Balancing costs** for renewables & forecast for **Guarantees of Origin**

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Our Baltic Ancillary Price Forecast provides you with detailed power market analysis and investment case data for batteries

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Technology and market development reports

- Overview of battery pipeline development
- Regulatory framework and qualification criteria for batteries, including details on neighbouring capacity markets
- Projections for battery CAPEX and OPEX by delivery year
- Reports and datasets follow the same format with content tailored to specific markets

Forecast data

- Day-Ahead and Intraday power prices
- Relevant ancillary service prices
- Including the TSO's projections of the ancillary market size

Investment cases

Standalone Battery

- At least four investment cases per country including:
  - For typical BESS durations: 2h vs 4h
  - Provided in Aurora's Central scenario
  - Participation in both wholesale and ancillary markets
- Projection of annual project margins to 2060
- IRR and net present value for entry years 2026 and 2029

Available in July!

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Publication
From Volatility to Value: Negative Prices and Batteries in the Baltics

Date
4 June 2025

Version
1.0

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