AURORA ENERGY RESEARCH

REDACTED

European Battery Market Attractiveness Report

March 2025

Aurora European Battery Markets Attractiveness Report: *How to use this report*

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This report is divided into 7 sections:

- **Section I *[Executive summary]*** gives an overview of the full report, highlighting the most attractive countries for battery investments, details of our ranking methodology, and provides an overview of advantages and disadvantages of regions.
- **Section II *[Introduction to battery storage]*** is split into two subsections. The first subsection introduces drivers for battery buildout and the second introduces battery storage cost components and Aurora's forecast of battery storage costs.
- **Section III *[Market size and outlook]*** provides details of the battery storage pipeline and grid connection queue across Europe and Aurora's Central forecast of battery storage buildout through to 2050, by battery duration.
- **Section IV *[Policy and regulatory environment]*** explores the key policy drivers for battery storage deployment and Government commitments and regulation. It also details the various markets and revenue streams available to batteries across the analysed countries.
- **Section V *[Revenue Streams]*** provides detailed analysis and outlook for the revenue streams introduced in Section IV, highlighting the most valuable markets and revenue streams in the different countries and assessing saturation risk across the markets.
- **Section VI *[Project economics]*** introduces the investment cases for battery storage, comparing gross margin stacks and their evolution over time and merchant IRRs for different project setups.
- **Section VII [Appendix]** details Aurora's underlying assumptions and modelling methodology
- **Section VIII *[Aurora's Flexible Energy Subscription Services]*** details Aurora's *Flexibility Energy Market subscriptions and offerings*

Please note that all presented data which feeds through to the rankings can be found in the accompanying Excel datasheet

If you are looking for…

- ***Country rankings:*** *read through Section I [Executive summary]*
- ***Project pipelines, Aurora's forecast for battery buildout and investment requirement:*** *go to Section III [Market size and outlook]*
- ***An explanation of the markets and detailed policy analysis for a specific market:*** *see Section IV [Policy and regulatory environment]*
- ***Aurora's central forecast prices for a particular market:*** *see Section V [Revenue Streams]*
- ***Aurora's investment case numbers for a particular asset:*** *see Section VI [Project economics]*

If you are using this report…

- **For project financing:** See sections I, V and VI to understand which markets are ripe for investment and where the most attractive IRRs are.
- **As an OEM**: See sections III and IV to understand which countries have a promising market outlook and favourable regulation.

Source: Aurora Energy Research

The 4th Edition of the Aurora BatMAR improves policy updates and market attractiveness metrics with added granularity

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The Aurora European Battery Market Attractiveness Report (BatMAR), first published in July 2022, assesses which markets in Europe are most attractive to invest in for Battery Energy Storage Systems (BESS). Since the 3rd publication, several changes have occurred in European BESS markets, which we examine in this 4th Edition.

What's new?

Refreshed and improved analysis and policy updates

1

- Refreshed gross margin and IRR analysis based on Aurora's latest power market forecasts
- Updated BESS cost projections reflecting recent lithium-ion trends
- Updated market overview on existing capacity, pipeline and financing conditions and key market players
- Updated analysis of battery revenue streams with special focus on saturation and weather risk and opportunities
- Updated outlook Policy and regulatory changes, including upcoming auction schemes, and with a special focus on challenges and opportunities arising from grid integration

Additional analysis

2

- More nuanced analysis and investment advice, depending on volume and risk appetite of market players
- New markets added: Overview of the Austrian, Swiss, Czech and Slovak market and additional in-depth analysis, including IRRs for Lithuania, Estonia, Bulgaria, Romania and Hungary
- Coverage of different set ups and strategies for battery projects, including indicative IRRs
- Capex forecast now is included in the Databook

Source: Aurora Energy Research

Aurora has a strong track record of acting as a market lending advisor to many BESS projects globally

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Aurora's price forecasts have been relied upon by lenders in recently completed transactions:

Rabobank, Santander, TriplePoint

£70m debt financing

49.9 MW BESS project of TagEnergy

LLOYDS BANK, Commonwealth Bank

124 MW solar and BESS portfolio

Lending advisor for BSR

CIP Copenhagen Infrastructure Partners, KLP, RIVAGE INVESTMENT

€300m debt financing

For Sunly's construction of 1.3 GW of solar, wind, storage, and hybrid parks

cefc

AUS $160m battery debt financing

Neoen's 300 MW/450 MWh Victorian Big battery

GREENPRINT CAPITAL

Debt and Tax Equity financing

300MW BESS asset of Perfect Power

Santander

Debt financing to Equitix

226MW two co-located projects (solar PV/wind and solar PV/wind/BESS)

NatWest, SIEMENS

100 MW energy park BESS

Debt financing for Sosteneo

Santander

100 MW portfolio of battery projects of Zenobe

First battery project financing in UK

HPS INVESTMENT PARTNERS, Deutsche Bank

$837m project financing

3x 160MW battery projects in ERCOT for Intersect Power

Commonwealth Bank, NatWest, LLOYDS BANK, Santander

£380m debt financing

battery storage portfolio of Gresham House

KFW IPEX-Bank

Lender advisor for $300m debt raising of Green & Clean Power's Solar & BESS in Arkansas

Santander, leumi, Goldman Sachs, bank hapoalim

£152 credit line

300MW BESS of Atlantic Green

Modelling storage is complex. Aurora's forecasts have underpinned the deployment of over 2.5GW of operational battery assets globally

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What is the challenge?

- Modelling a consistent set of day-ahead, real-time and Ancillary service prices accounting for opportunity costs
- Understanding and modelling detailed rules in AS[1] markets, including responding to market changes
- Capturing the role of weather in driving scarcity and AS[1] procurement – annual averages are irrelevant to storage economics, especially as renewables penetration increases

Future of the market (difficult to model)

- Dispatching assets against multiple price series accounting for imperfect foresight, degradation, warranties, route to market, and asset characteristics

Future of the asset in the market (easier to model)

How do we address it?

- ✓ Offer valuations for a range of standard and bespoke market scenarios
- ✓ Work closely with clients to ensure the valuation is specific to their asset or portfolio characteristics
- ✓ Model storage margins for all major business models including arbitrage, Ancillary Services, and hybrid
- ✓ Dispatch against consistent day-ahead, real-time and AS prices
- ✓ Account for degradation and imperfect foresight
- ✓ Present results in slides and cashflow model at monthly, quarterly and annual granularity

Example transactions

- **2018** — Banked by Santander on first project financing of battery storage in the UK for 100MW Zenobe portfolio
- Sell-side market advisory for then-largest operational battery storage portfolio in Europe, STEAG's 90MW bid into the FCR market
- **2019** — Supported PE fund on $50m acquisition of storage developer; bidding support for large developer for DS3 auctions
- **2020** — AUS $50m in debt financing for 50MW extension of Neoen's Hornsdale battery – first battery project financing in Australia
- Debt and equity raise for 100MW battery portfolio
- **2021** — Development/financing of 150MW Hazelwood BESS project
- **2022** — Sell-side advisor for 1.1GW of battery storage from BMES to UBS Asset Management and Cypress Creek Renewables
- **2023** — Buy-side advisor for Engie's acquisition of Broad Reach Power
- **2024** — Sell-side advisor for 600MW/2400MWh of battery project

1) Ancillary Services.

Source: Aurora Energy Research

Flexibility Market add-on service: Provides detailed power market analysis and investment cases for batteries in 15 European markets

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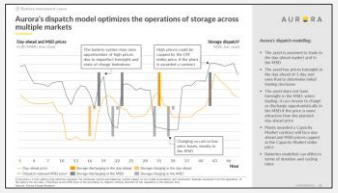
Flexibility Market add-on service

Forecast reports & data

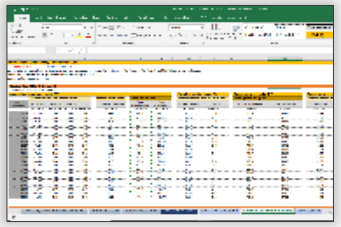
Technology and market development reports

- Overview of battery pipeline development
- 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

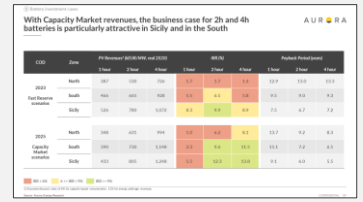
- Central case forecast prices provided at settlement period granularity until 2050
  - Wholesale power prices
  - Balancing market prices
  - Ancillary services prices



Investment cases

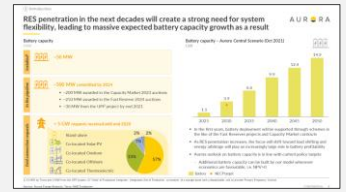
Standalone Battery

- At least six 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 at least two entry years



Co-location

- Provided in markets with favourable economic or regulatory opportunities
- At least two investment cases for battery co-located with solar PV and/or onshore wind
- Annual project margins to 2050. IRR and NPV for at least two entry years



Ongoing analyst support

Throughout the year you can contact us to discuss questions related to our analysis and our thoughts on flexibility market and policy developments.

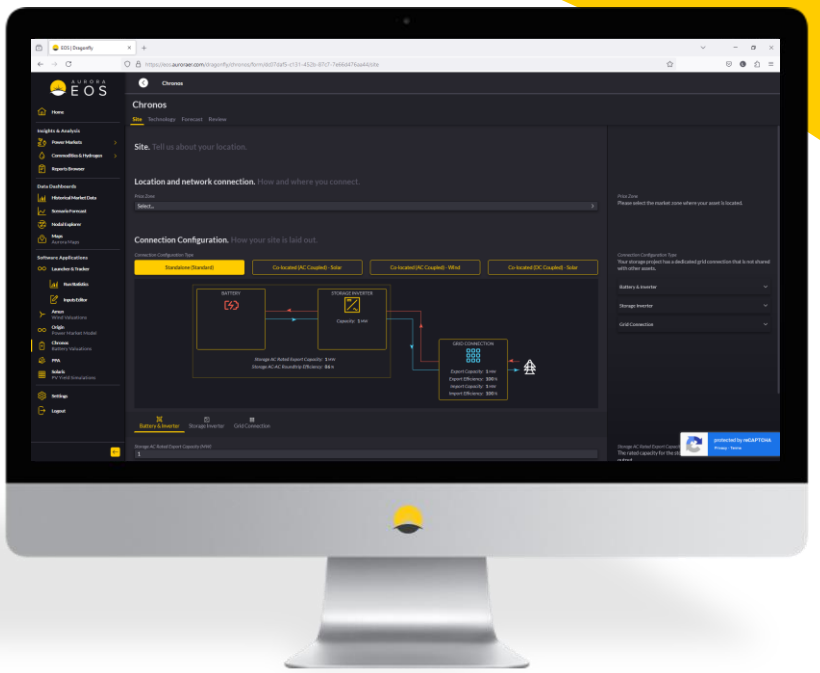
Source: Aurora Energy Research

CHRONOS

Battery valuations, perfected

Chronos allows you to evaluate any storage asset or project using Aurora's cutting-edge proprietary battery dispatch engine

- **Thorough:** Accounts for all site-specific value drivers
- **Reliable:** Backed by Aurora's trusted forecasts and team of experts
- **Bankable:** Methodology recognised by banks and investors, with reliance available
- **Comprehensive UX:** Intuitive interface that empowers user driven analyses
- **Efficient:** Evaluate as many opportunities or scenarios as you require, without any consultancy lead times, for just one yearly fee



Intuitive 4-step process:

1. Select your scenario & site settings
2. Input your technology settings
3. Define your business model
4. Analyse your result

What can Chronos be used for?

- Transactions
- Project Design Optimisation
- Portfolio Valuation
- Optimisation Benchmarking

Trusted by industry leaders:

Adaptogen Capital · Brookfield Renewable Energy Partners · FORSA Energy · Harmony Energy Income Trust PLC · Constantine · Renewable Power Capital · West Burton Energy · frv · telis · Eku · Field · centrica · Elgin Energy · CIP Copenhagen Infrastructure Partners · Sunco Capital · Thrive Renewables · Redelfi Corp · TotalEnergies · Cubico Sustainable Investments · SandbrookCapital · PacificGreen Technologies Group · British Solar Renewables · equitix · Qualitas energy · SMS · InterGen · Armstrong · OnPathEnergy · Apatura · tagenergy · Integrum Renewable Energy

Agenda

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Executive Summary

*The information in this report draws on Aurora's Flexible energy market subscriptions to provide you with an overview of European battery markets. For a deep dive into country specific markets, view our subscription services, or contact Alex Hutcheson (alex.hutcheson@auroraer.com) about finding a solution relevant to your needs.

Source: Aurora Energy Research

Aurora determines the attractiveness of battery markets based on in-depth modelling and expert interviews

The Battery Market Attractiveness Report is constructed via inputs from Flexible Energy and Power & Renewable market reports, combined with interviews with Aurora's in-house experts. The findings from these are then synthesised to develop this report, which serves to rank Flex markets by attractiveness.

Inputs:

1. **Power and Renewables Market Forecasts:** Comprehensive outlook of key policy and technology developments in European Power Markets, incorporated into input assumptions in Aurora's proprietary power market modelling software, **Origin**.
2. **Flexible Energy Forecasts:** Overview of recent development in European Flexible Energy Markets, and the corresponding impact of market conditions on investment cases for flexible energy assets, such as battery storage and gas reciprocating engines. This is conducted using our proprietary Battery Asset Dispatch software, **Chronos**[1].
3. **Interviews with in-house experts:** Interviews with experts across 15 different Flex markets, enabling comparison of markets across policy risks, opportunities, revenue streams etc.

1) Aurora Energy Research offers a Chronos subscription service, allowing for asset dispatch with custom battery parameters to help with bespoke battery valuations. The service is currently available in GB, Italy and Iberia, and is due to launch in Germany in 2025.
Sources: Aurora Energy Research

Aurora's rating combines 11 metrics to derive an overall attractiveness score for 28 European grid scale battery markets

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The overall market attractiveness score for each European battery market covers the following four categories and 11 metrics, which are set out in detail in this report.

Categories and metrics	Weighting	Rationale	Source of data
Market size and outlook	**25%**		
1 Projected battery buildout by 2030	40%	Indicates expected future market size	Aurora fundamental modelling*
2 Projected CAPEX spend until 2050	30%	Indicates future investment need, reflecting storage duration and repowering	Aurora fundamental modelling*
3 Current installed battery capacity	30%	Demonstrates current market size and impact on energy security	Aurora fundamental modelling*
Policy environment	**25%**		
4 Availability and contractability of revenue streams	*30%*	Indicates availability and long term contractability of revenues	Aurora analysis
5 Flexibility drivers (i.e. Renewables targets)	*30%*	Demonstrates policy ambition around renewables deployment	Aurora analysis
6 Grid integration	*30%*	Indicates current regulatory risks around grid connection and fees	Aurora analysis
7 Competitive risk	*10%*	Indicates regulatory risks around aggregation[1], electrolysers and EVs	Aurora analysis
Revenue streams for battery storage	**25%**		
8 Average wholesale market daily spreads	*50%*	Indicates the value available from energy arbitrage	Aurora fundamental modelling*
9 Frequency and balancing markets saturation risk	*20%*	Demonstrates the risks of market saturation	Aurora analysis
10 Capacity market revenues	*30%*	Indicates the value available from receiving capacity market payments	Aurora analysis
Business models and cases	**25%**		
11 Indicative merchant IRR for projects starting in 2027/28 (incorporates IRRs for 1,2,4 hr and co-located assets)	*100%*	Captures the commercial viability of new build merchant projects for final investment decisions in the next few years	Aurora fundamental modelling*

1) Aggregation of Distributed Energy Resources, such as behind-the-meter batteries and demand-side response
** Detailed analysis and forecasts available in Aurora's Flexibility Energy Market subscriptions for individual countries.*
Source: Aurora Energy Research

Different markets emerge top across the four key categories, highlighting diverse investment opportunities

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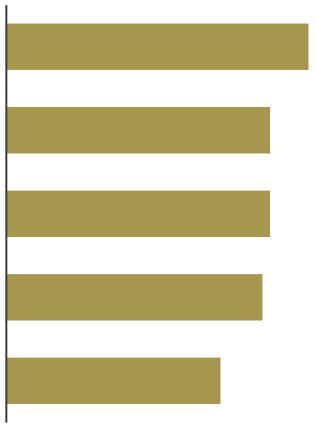
Market size and outlook

Policy environment



Revenue streams

Project economics

1) Meccanismo di Approvvigionamento di Capacità di Stoccaggio Elettrico;

Source: Aurora Energy Research

The most attractive European market for battery storage is [redacted], followed by [redacted] and [redacted]

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Installed capacity of battery storage across Europe currently stands at [redacted] GW, making up less than 1% of total installed capacity. It is projected to grow over [redacted] to [redacted] GW by 2030, requiring [redacted] bn € CAPEX investment.

Source: Aurora Energy Research

[redacted] has overtaken [redacted] as the most attractive market; [redacted] also moves up the ranks to take third place

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Region	Current rank[1] (4th edition)	Previous rank (3rd edition)	Key change drivers and recent highlights
	1	▲	
	2	▼	
	3	▲	
	4	▲	
	5	▼	
	6	▼	
	7	▲	
	8	▲	
		▼	
	10	▼	
		=	

1) Capacity Market.

Source: Aurora Energy Research

[redacted], [redacted], [redacted], [redacted] and [redacted] are attractive for smaller scale investors with a higher risk appetite

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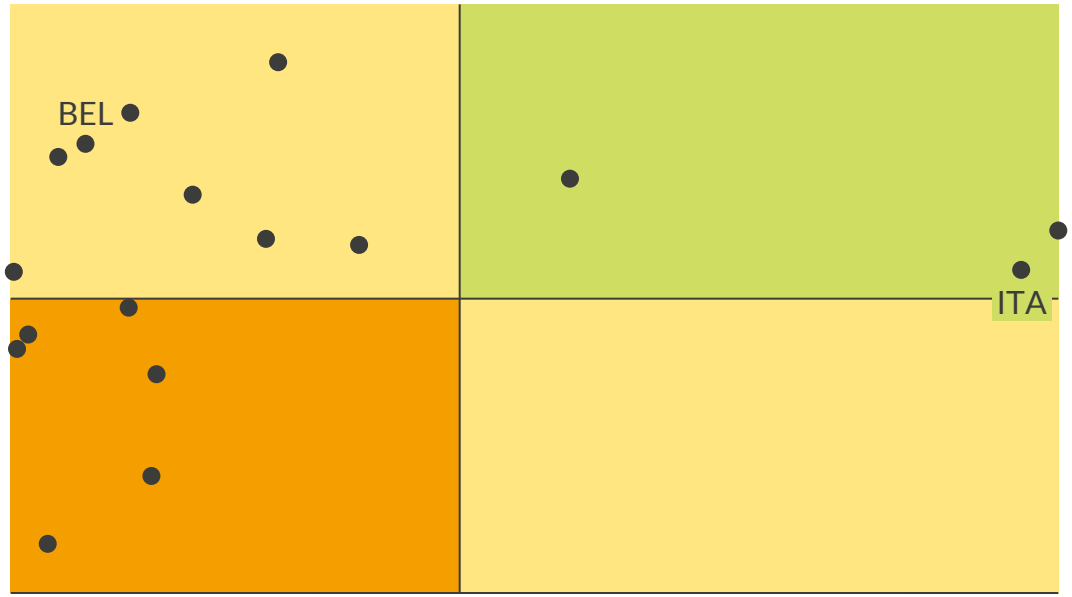
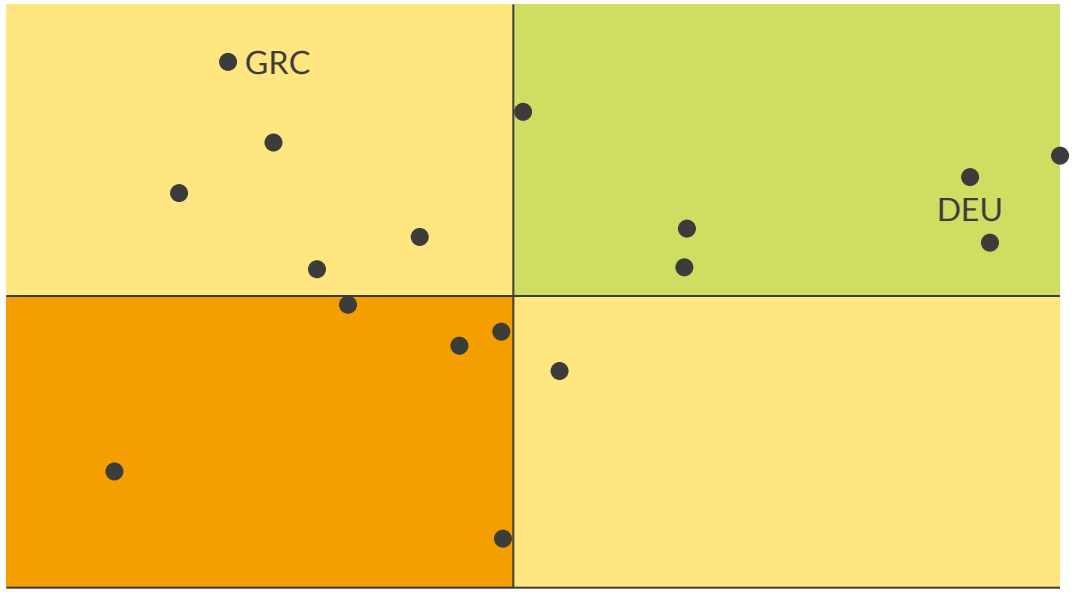
Project economics



Total investment volume until 2050, mil €



Risk indicator, high score indicating low risk

[redacted]

[redacted]

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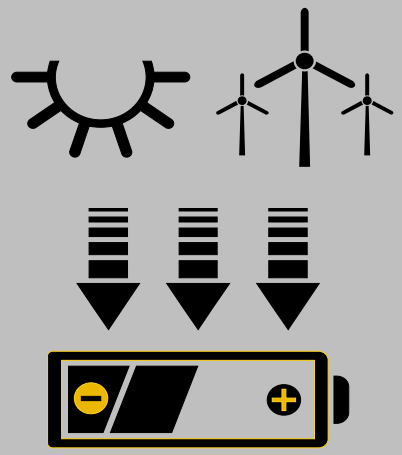
Executive Summary

Introduction to battery storage



Source: Aurora Energy Research

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

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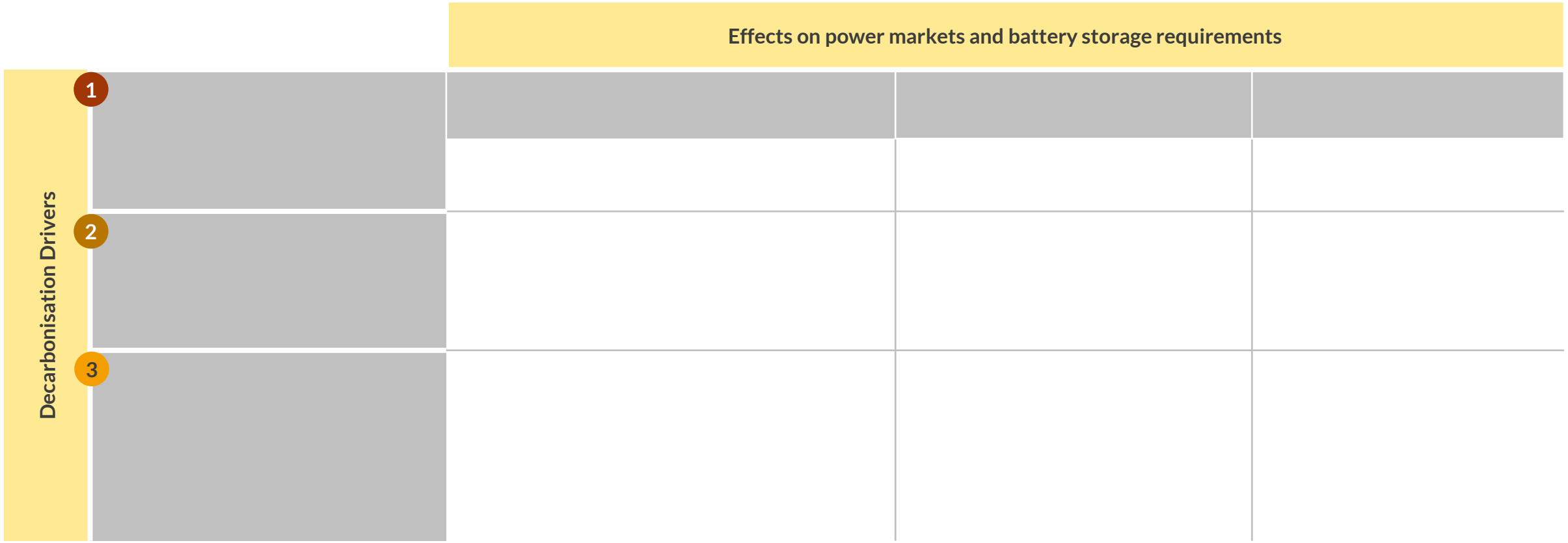

Impact on Battery Storage Requirements

Sources: Aurora Energy Research, Ofgem

1 1,848GW of variable renewables capacity is expected by 2050, accounting for 70% of total generation

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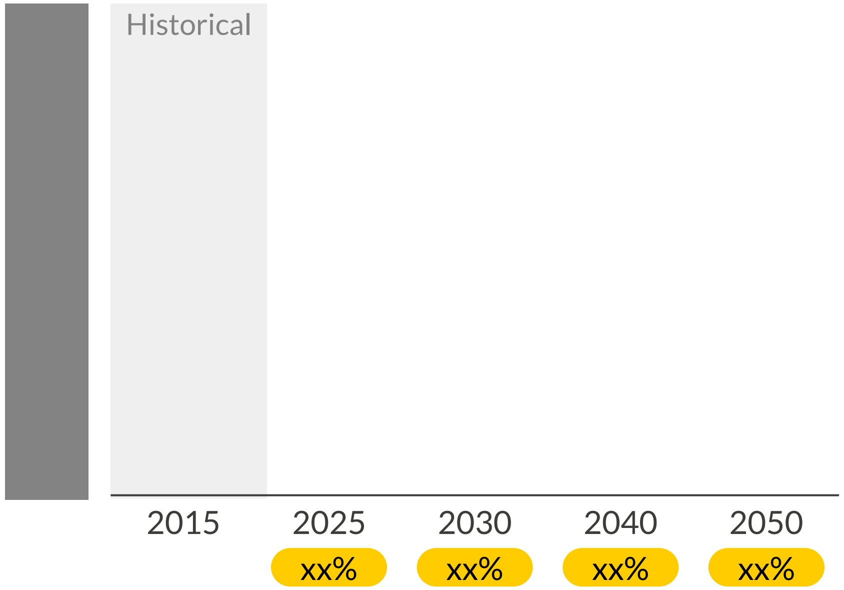
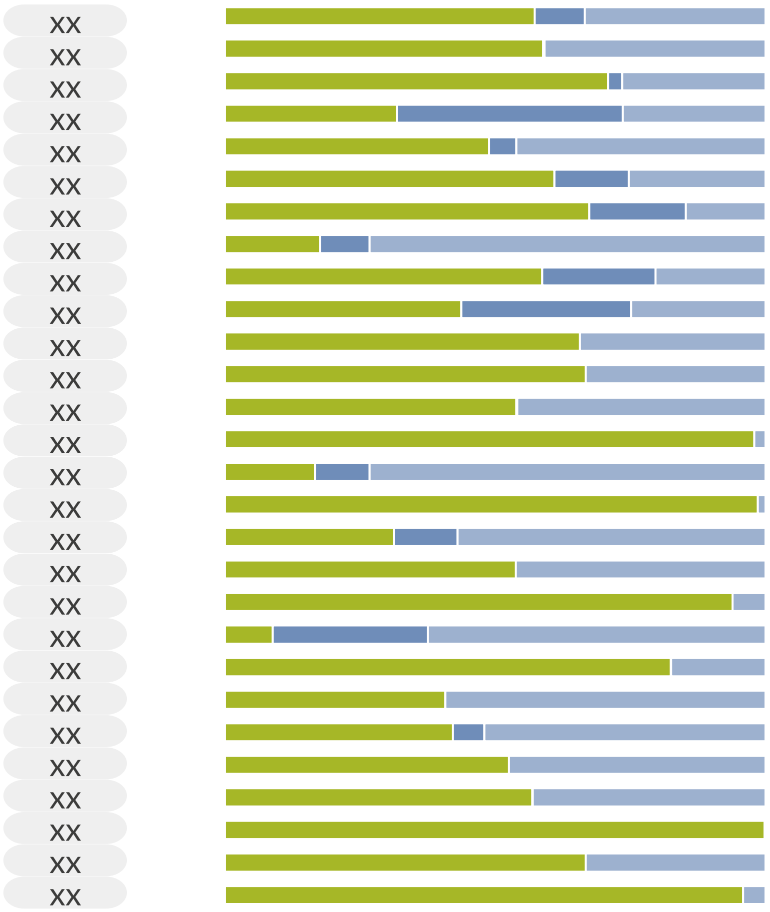
Installed variable renewable capacity in Europe (Aurora Central scenario), GW



- Europe's installed capacity of solar, onshore, and offshore wind is expected to reach [redacted] and exceed [redacted] in 2030 and in 2050, respectively.
- Increased penetration of solar PV and wind technologies leads to a [redacted] base percentage point increase in the variable RES share of generation between 2025 and 2050.

Installed variable renewable capacity by 2030 (Aurora Central scenario), GW



Offshore Wind | Onshore Wind | Solar PV | xx 2030 capacity, relative to 2025 (GW) | xx% Variable RES share of generation

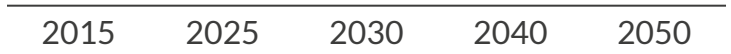
2 A [redacted]% decrease in generation from thermal assets by 2030 results in the loss of inertia and other grid stability provisions

Evolution of thermal generation in Europe[1]
TWh

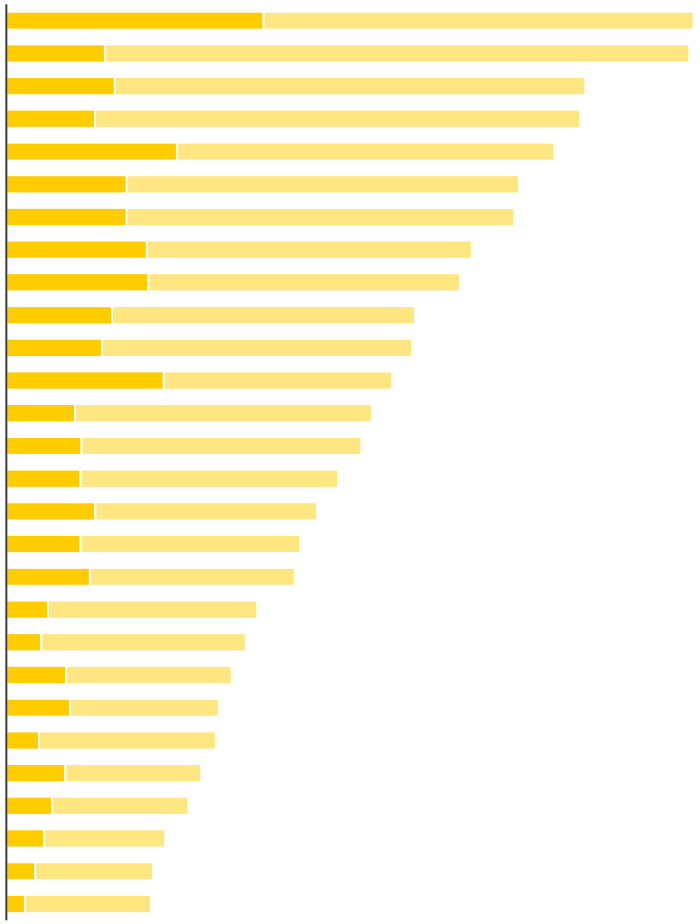
Peak demand
GW

3 Power demand in Europe is expected to increase by [redacted]% from 2025 to 2050, driven by increased electrification across sectors

Annual power demand in Europe
TWh



Percentage growth in demand by 2050 relative to 2025
%



- In Aurora's Central outlook, European power demand increases significantly across sectors due to the electrification of industry (included in base demand) and heating, as well as increased demand for electric vehicles and hydrogen production.

  [redacted] TWh of electricity ([redacted]% of demand) in 2050 is used by electrolysers to produce green hydrogen, largely for consumption in industrial processes.

Hydrogen | Road transport | Heat | Base power demand | Historical | 2025-2030 | 2031-2050

Sources: Aurora Energy Research, Eurostat

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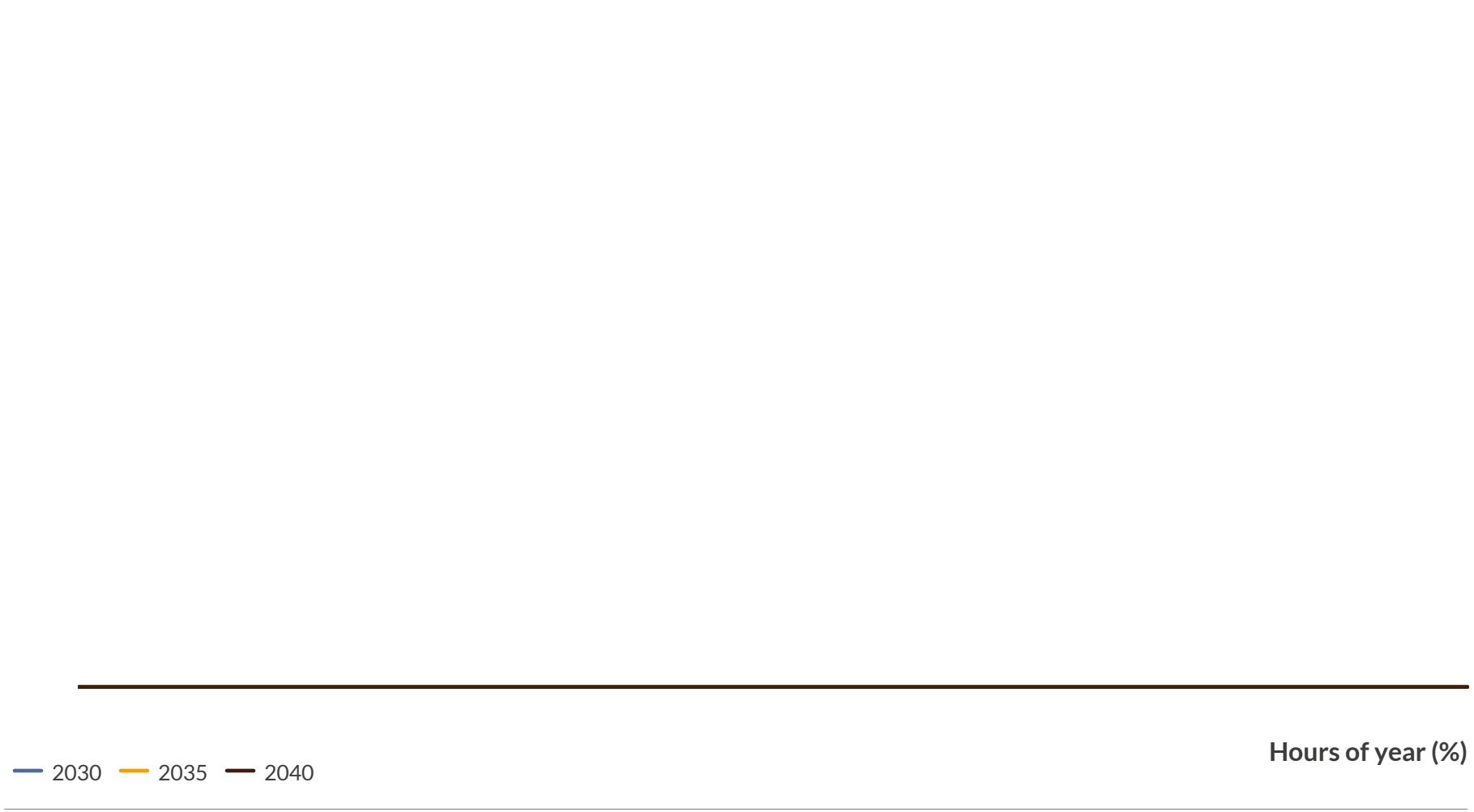
This is a redacted sample of the European Battery Market Attractiveness Report. If you are interested in the full report, contact Alex Hutcheson (alex.hutcheson@auroraer.com)

Periods of high renewables generation will increase by [redacted] p.p. in the 2030s, creating significant opportunities for battery charging

Residual demand curves, [redacted] example

GW



Source: Aurora Energy Research

This is a redacted sample of the European Battery Market Attractiveness Report. If you are interested in the full report, contact Alex Hutcheson (alex.hutcheson@auroraer.com)

To ensure continued grid operability, additional markets are used across Europe to procure a variety of ancillary services

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	Objective	Methods	Commercial availability
1 Energy Balancing (Reserve)	Energy supply and demand should be kept equal, to ensure an efficient market and well-functioning system	Instructing plants to either increase or decrease generation, both ahead of gate closure and in real time, often manually dispatched	high
2 Frequency (Response)	System frequency is required to ensure proper system function. Deviations from standard must be corrected in a timely fashion	Automatic dispatch of ultra-fast increase or decrease of energy in real time determined by deviations in the system frequency	
3 Congestion and constraint resolution	Transmission constraints and grid congestion can make cost-effective generation infeasible to transmit to demand	Instruction to curtail generation in congested areas ahead of gate closure and in real time or increase demand e.g.. through batteries	
4 Inertia (Stability)	Sufficient inertia is required to reduce the speed of frequency deviations, and enable a timely response	Increasing the amount of synchronous generation on the system, both ahead of gate closure and in real time either through conventional sources or alternatives such as synchronous compensators, synthetic inertia from batteries etc	
5 Restoration / Black start	In the unlikely event of a blackout, grid operators must maintain the capability to restore the system	Pre-contracted service which can repower the power system in the event of a black-out	
6 Voltage	Voltage levels must be maintained to ensure proper functioning of the system	Procurement of reactive power, potentially alongside active power, to increase voltage levels	
7 Short circuit levels (SCL)	SCL is the amount of current that flows during a short-circuit fault (e.g.. equipment failure). High SCL must be maintained to ensure system stability in the event of a fault.	Increasing the amount of virtual synchronous generation on the system, Procurement of long term SCL contracts e.g.. through the Stability Pathfinders in Great Britain	low

Sources: Aurora Energy Research, National Grid

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A range of technologies can help support intermittent renewables by storing energy

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Energy storage devices, charged from the grid or intermittent renewables like solar PV and wind, store surplus energy until needed, then discharge it back into the grid to balance the system and enable further renewable integration. Energy storage units can be categorised based on their storage technology.

Focus of this report

Type	Electrochemical	Chemical	Mechanical	Electrical	Thermal
Example	• Li-ion battery • NaS battery • Flow battery	• Ammonia • Hydrogen • Methanol	• Compressed air energy storage • Pumped hydro • Gravity based storage	• Supercapacitors	• Sensible heat storage • Latent heat storage
Deployment scale[1]					
Capex[2]					
Dispatch speed[3]					
Energy density					

1). Deployment scale refers to currently installed energy storage capacity for grid balancing purpose. 2). Capex ratings are current and use li-ion battery Capex as benchmark; mechanical energy storage capex refers to pumped hydro. 3). Dispatch speed for chemical energy storage refers to hydrogen storage.

Batteries store electricity by converting between electrical and chemical energy when charging and discharging

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What is a Battery Energy Storage System (BESS)?

- A battery stores electrical energy by converting into chemical energy within chemical bonds of battery components, as a form of electrochemical storage.
- Battery Energy Storage Systems (BESS) are large, utility-scale assets that combine many battery cells into a packed structure, aggregating to give larger power capacities and including the necessary electronics, control systems and hardware to enable connection to the power grid.
- BESS assets typically charge and discharge from the grid, generating revenue through energy trading in wholesale or balancing markets, or through offering ancillary services to the grid such as frequency response and voltage control.

What are 'typical' characteristics of currently deployed utility-scale BESS assets?

Battery technology

Li-ion

- Most utility-scale batteries to date are based on lithium-ion chemistries. Other technologies[1] are yet to reach the same levels of commercial deployment but are maturing.

Power Capacity

10 – 500MW

- Power capacity refers to the maximum power that BESS can charge or discharge at. Though utility scale capacities have typically been under 100MW, larger projects have been emerging in some markets.

Duration

1 – 4 hours[2]

- Duration refers to the length of time that BESS can operate at its maximum power capacity, given the energy capacity[3] of the BESS.
- Duration is defined by dividing energy capacity (MWh) by power capacity (MW).

Grid connection

Grid-connected

- Utility-scale batteries are typically connected to the grid through the distribution network, and increasingly the transmission network, or sometimes co-located with a renewable asset.

1) For more information on alternative technologies, see slide 30; 2) 8 hour duration BESS assets are emerging in project plans, though there are no such systems in operation in Europe as of yet; 3) Energy capacity is the total amount of energy able to be stored by the asset, defined in megawatt-hours (MWh).

Source: Aurora Energy Research

Batteries are one of multiple established technologies able to provide system services, with a competitive edge over other technologies

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		Pumped Storage	Lithium-ion battery storage	Reciprocating Engines	Demand Side Response (DSR)
Characteristics	CAPEX, €/kW				
	Efficiency, %				
	Response time				
Ancillary Services	Frequency (Response)				
	Inertia (Stability)				
	Energy Balancing (Reserve)				
	Congestion and constraint resolution				
	Voltage				
	Restoration / Black start				
	Short circuit levels (SCL)				

● More applicable ○ Less applicable

Source: Aurora Energy Research

Lithium-ion batteries remain the dominant electrochemical technology for grid-scale storage due to technical and market maturity

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Overview of selected alternative electrochemical energy storage technologies

2024 operational and pipeline BESS capacity across Europe, MW

Sources: Aurora Energy Research, EASE, RedT, Invinity, Highview Power, Lazard, REEM, Hydrowires, IRENA, Fraunhofer ICT, TU Delft, Enel, Stadtwerke Rostock and Kiel, US EIA, L. Tang et al (2023), Utility Dive, , Invinity, Terna

Li-ion batteries oversupply is driving down prices, reducing battery system CAPEX in the short term compared to our previous forecast

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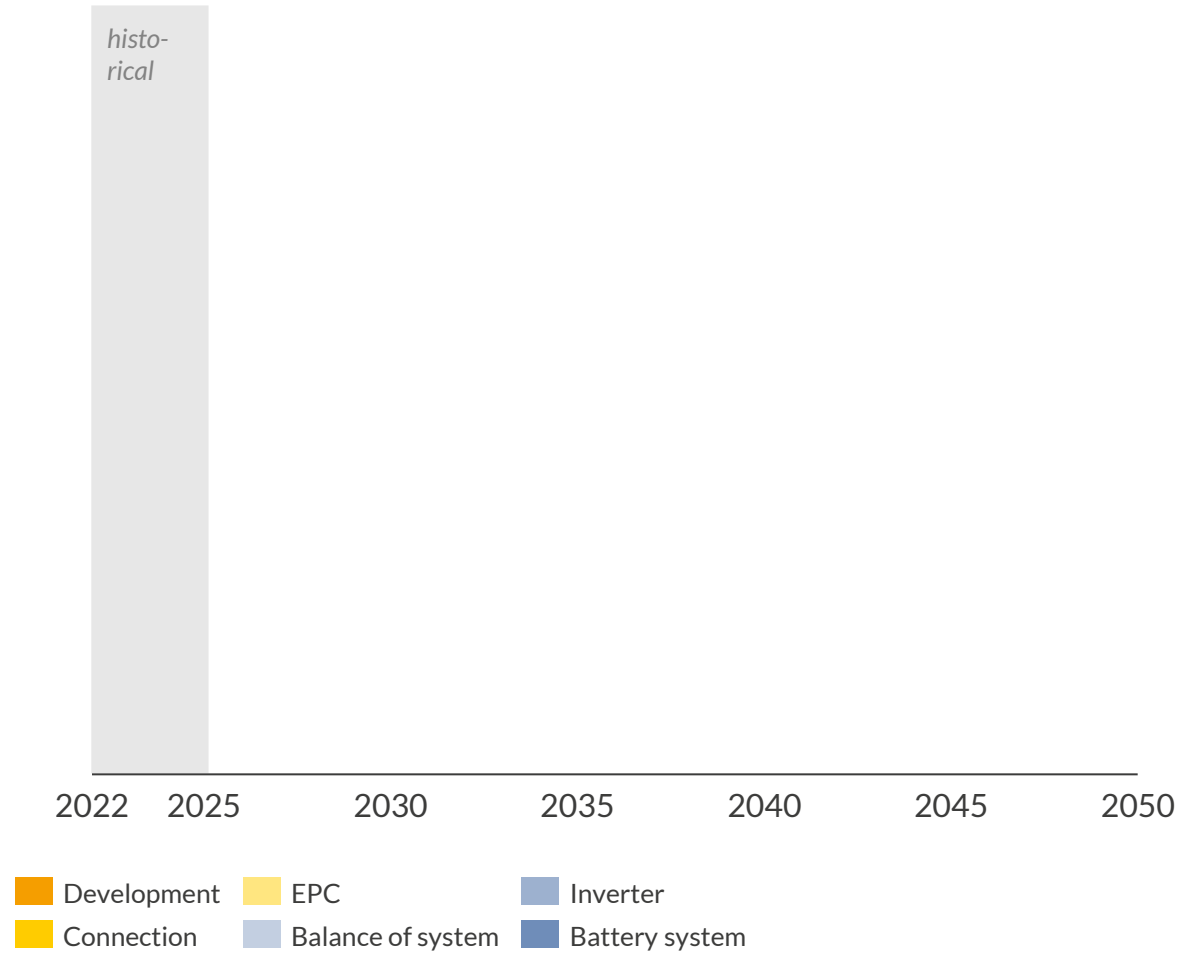
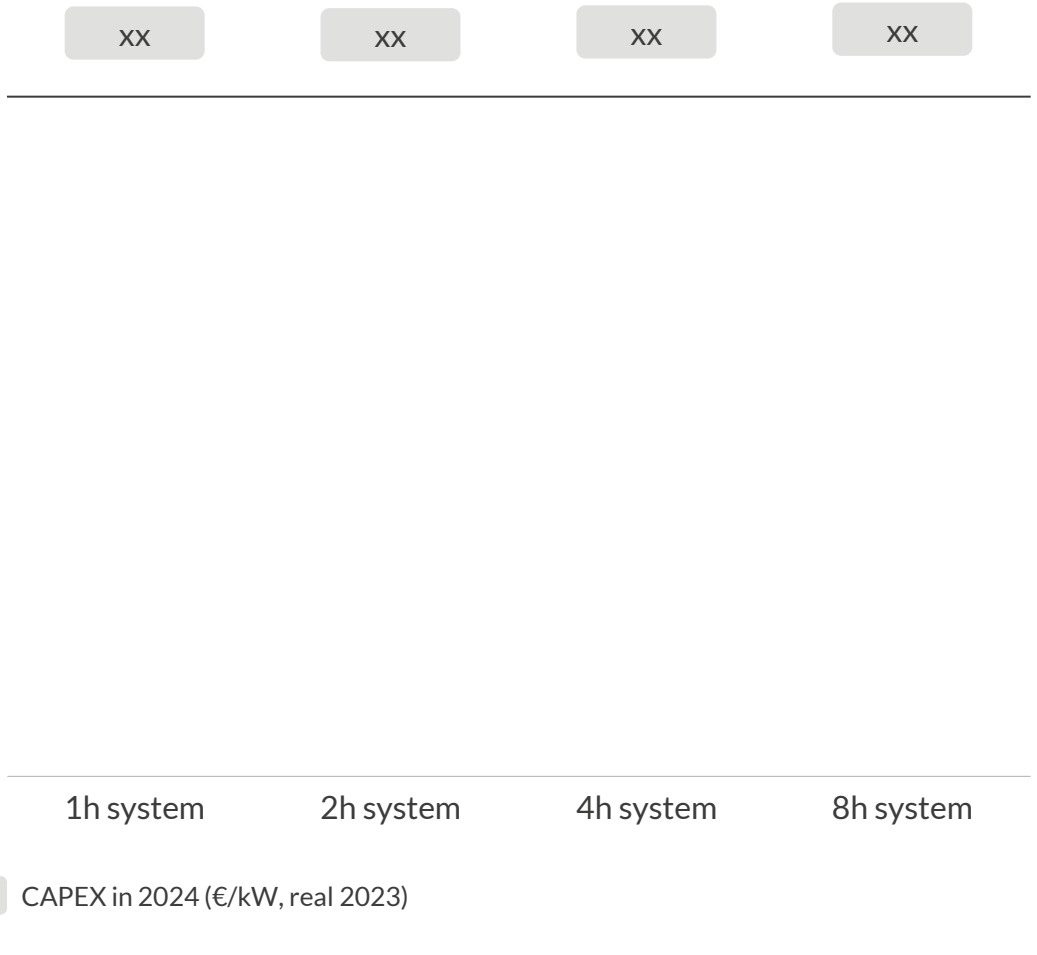
Li-ion battery total system costs – 2h asset
€/kW, real 2023



CAPEX changes from 2024 to 2030 by component
€/kW, real 2023



Source: Aurora Energy Research

After peaking in 2022 anode, cathode prices have dropped [redacted]%, yet copper prices still exceed early 2021 levels

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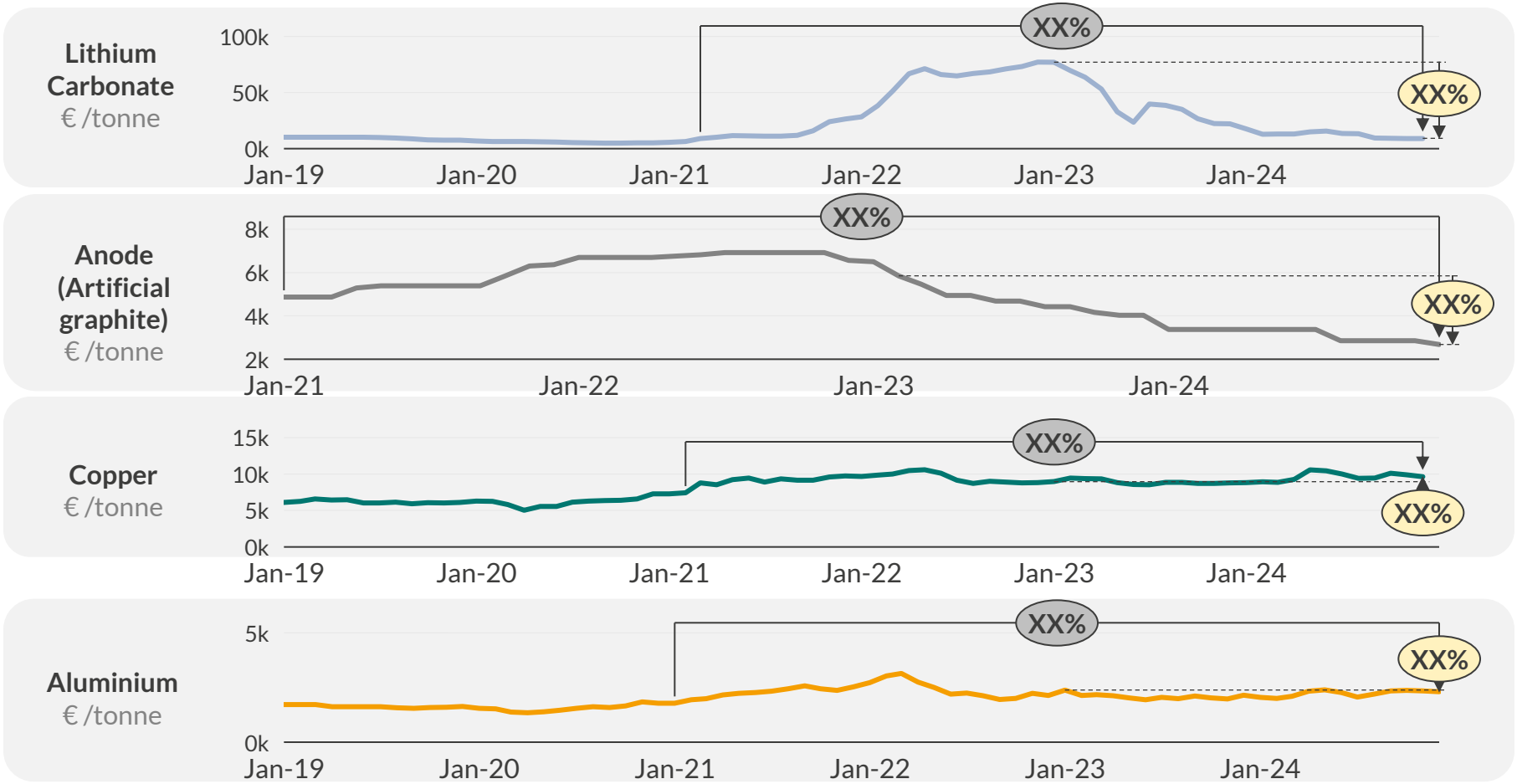
Raw material prices



Sources: Aurora Energy Research, MySteel, UK Investing

- Cathode prices experienced a sharp increase in 2022. But the trend reverted to a rapid drop since 2023 ongoing in 2024 due to 1) oversupply of lithium, 2) weak demand for EVs. Market uncertainty impacts lithium producers heavily.
- After rising in early 2022, graphite prices remained at a high plateau but began to drop in Jan 2023. Electrolyte prices also dropped by over [redacted]% since the start of 2023. Copper prices have increased since March 2024, reflecting the market's high expectations of a future shortage in supply.
- Both cathode and electrolyte use raw materials that are derivatives of Lithium as a main raw material. The decreasing spot price of Lithium is therefore linked to the decrease in the overall CAPEX.

Agenda

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Executive Summary

Market size and outlook

Source: Aurora Energy Research

[redacted] is currently the leading market in terms of size and outlook, followed by [redacted] and [redacted]

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Market size and outlook

Countries are assessed in terms of their market size and outlook for batteries between 2024-2030, based on three metrics shown below. An overall score for the market size indicator is assigned between 0-10 reflecting the specified weighting of the metrics.

Metric	Weighting	Rationale
1 Projected battery buildout by 2030	40%	Indicates expected buildout between 2025 and 2030, based on Aurora's Central scenario
2 Projected CAPEX spend until 2050	30%	Indicates expected future investment need, accounting for required battery durations and repowering
3 Current installed battery capacity	30%	Indicates current market size , ranked in milestones (>1GW, >0.25GW, >0GW installed)

Rank	Region	Market attractiveness score
1		
2		
3		
4		
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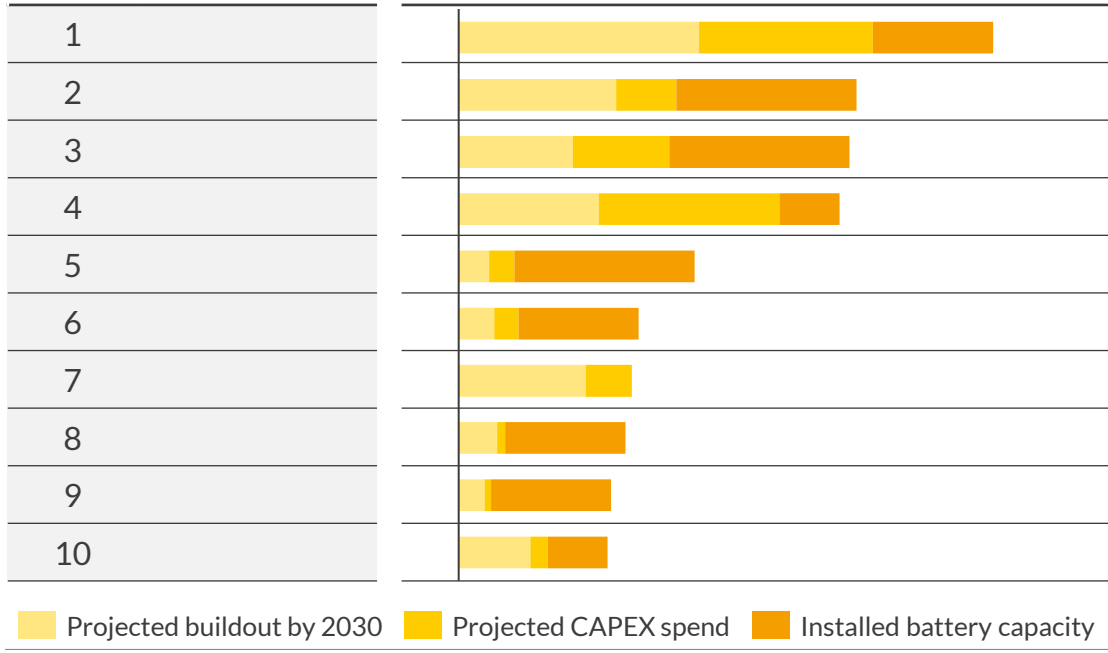
9		
10		



Source: Aurora Energy Research

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Based on Aurora's Central scenario, grid scale battery storage could grow to [redacted] GW by 2030

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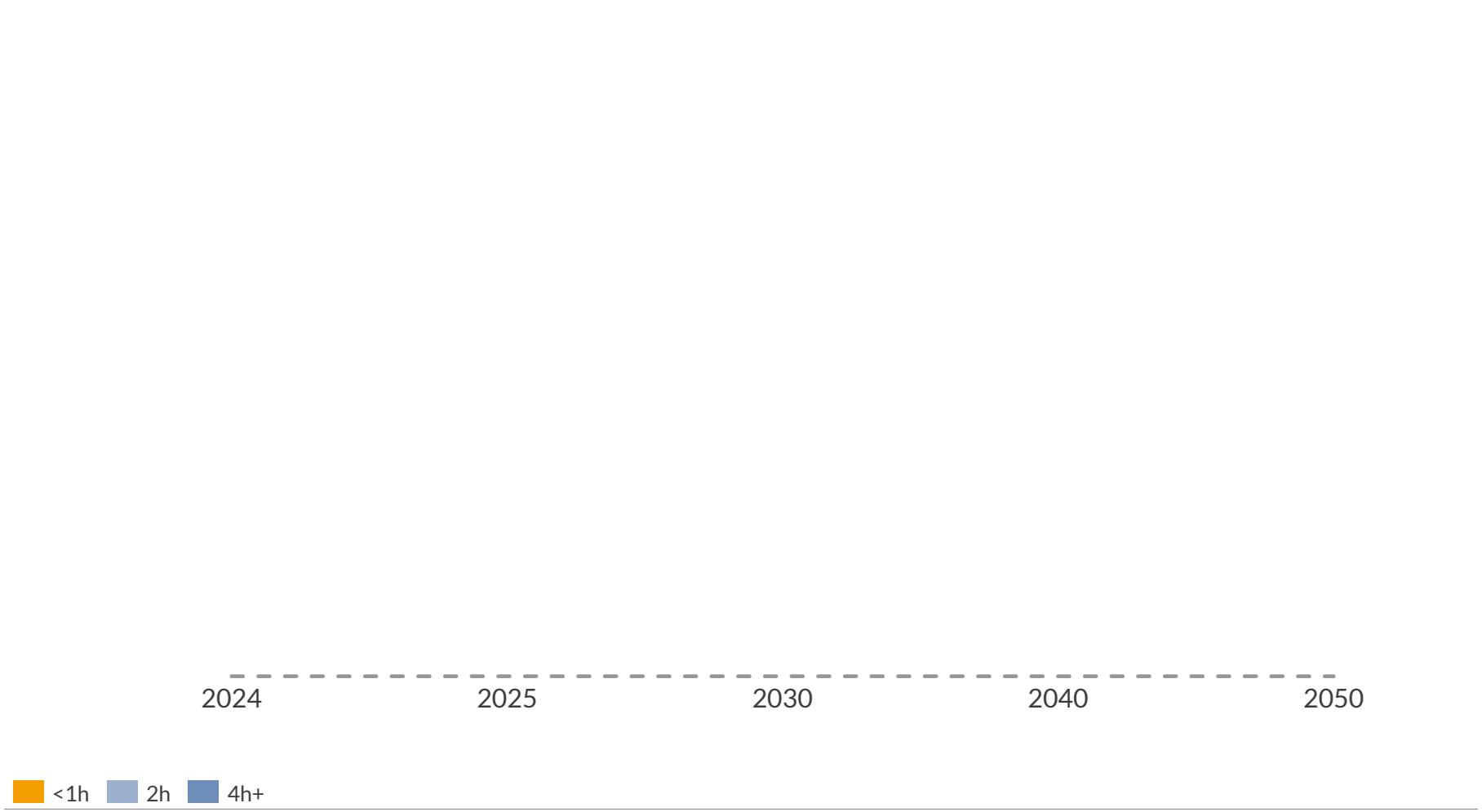
Installed grid-scale battery capacity in Europe (Aurora Central scenario)
GW



1) Announced pipeline capacities are taken from confirmed capacities with capacity market contracts, confirmed pipeline capacities holding grid connection agreements from TSOs or DSOs, or auction procurement targets.
Sources: Aurora Energy Research, Eurostat

Aurora's 2030 forecasted capacity denotes [redacted] GW of capacity additions from 2024, mainly deployed in [redacted], [redacted] and [redacted]

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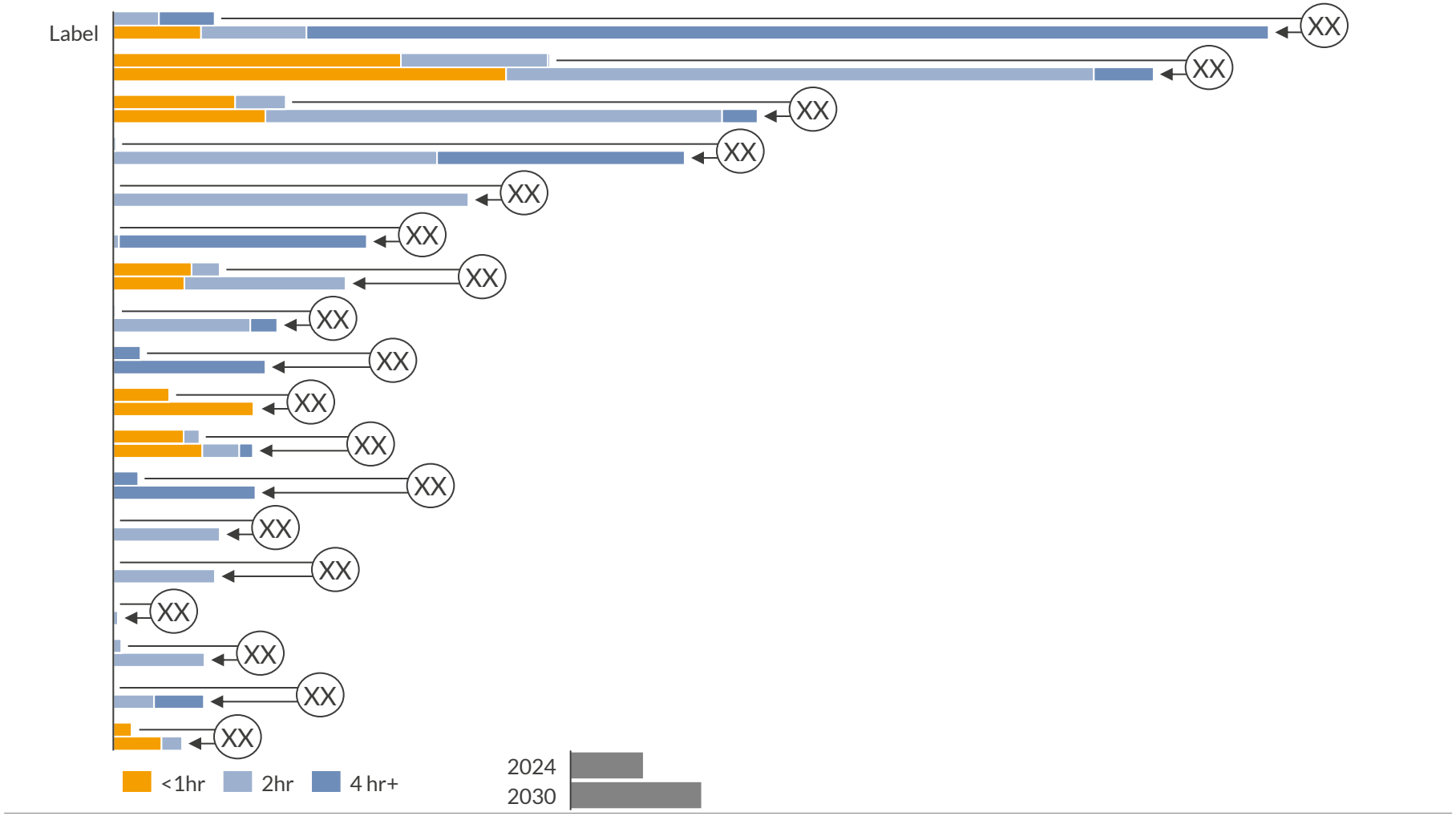
Installed utility-scale battery capacity in 2024 vs Aurora's 2030 forecast

GW



Sources: Aurora Energy Research, Eurostat

The projected battery capacity additions represent a cumulative investment opportunity of almost [redacted]bn€ between 2025-50

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Total CAPEX spent on grid-scale batteries
bn € (real 2023)

2025-30

2031-40

2041-50

Source: Aurora Energy Research

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Full delivery of the current high probability pipeline would see battery capacity in Europe grow to over [redacted] GW by 2030

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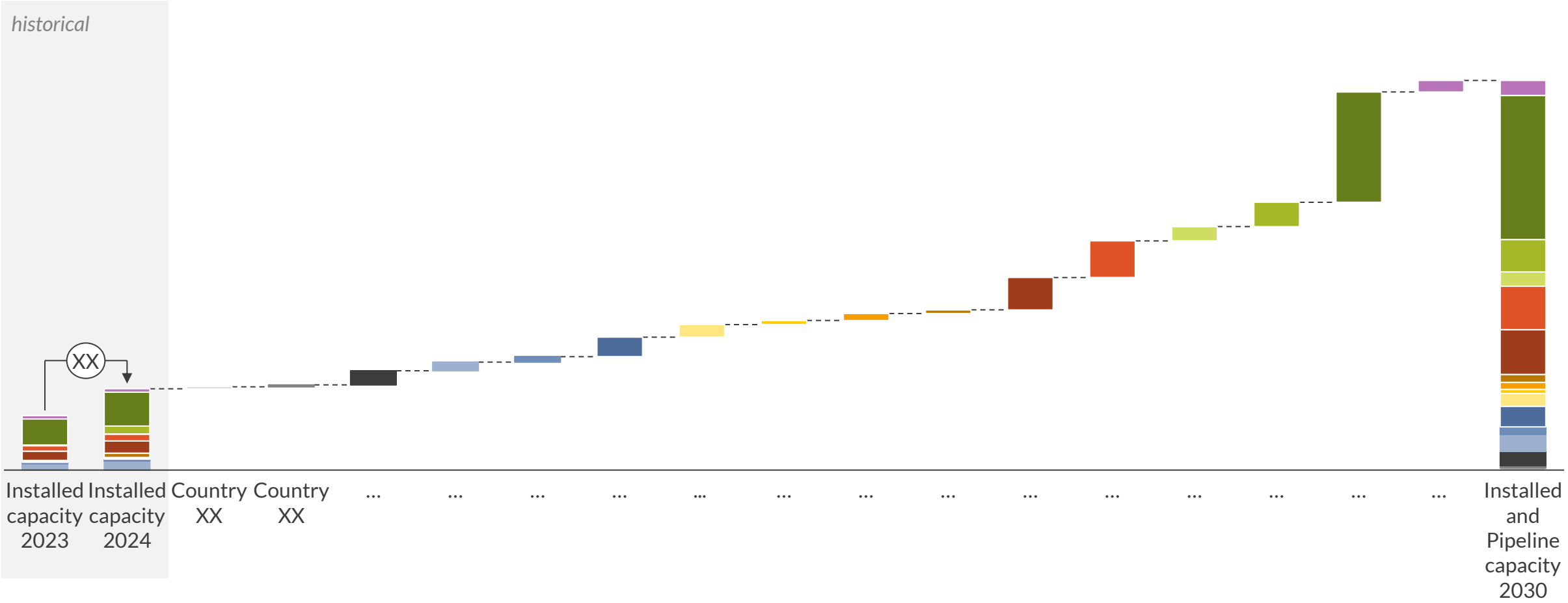
Near-term project pipeline of grid-scale batteries
GW, nameplate



Announced pipeline capacity exhausts [redacted]% of Aurora's 2030 forecast, though opportunity remains in some markets

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Pipeline vs Forecasted Capacity – Europe

GW

Source: Aurora Energy Research

Grid connection queues are even higher than pipeline capacity, but the likelihood of realisation of projects in this stage is low

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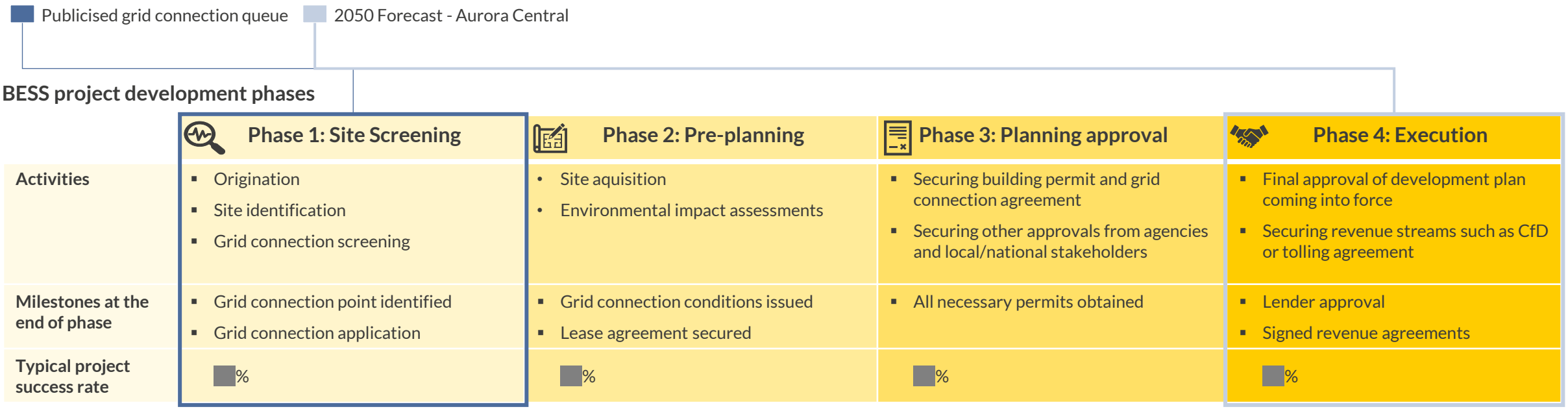
BESS publicised grid connection queue
GW, nameplate



Source: Aurora Energy Research, Montel News, France Ministry of Ecological Transition, NESO, Litgrid, Terna, TenneT

Total battery storage in Europe reached over [redacted] GW in 2024; the developer and investor landscape for assets is fragmented

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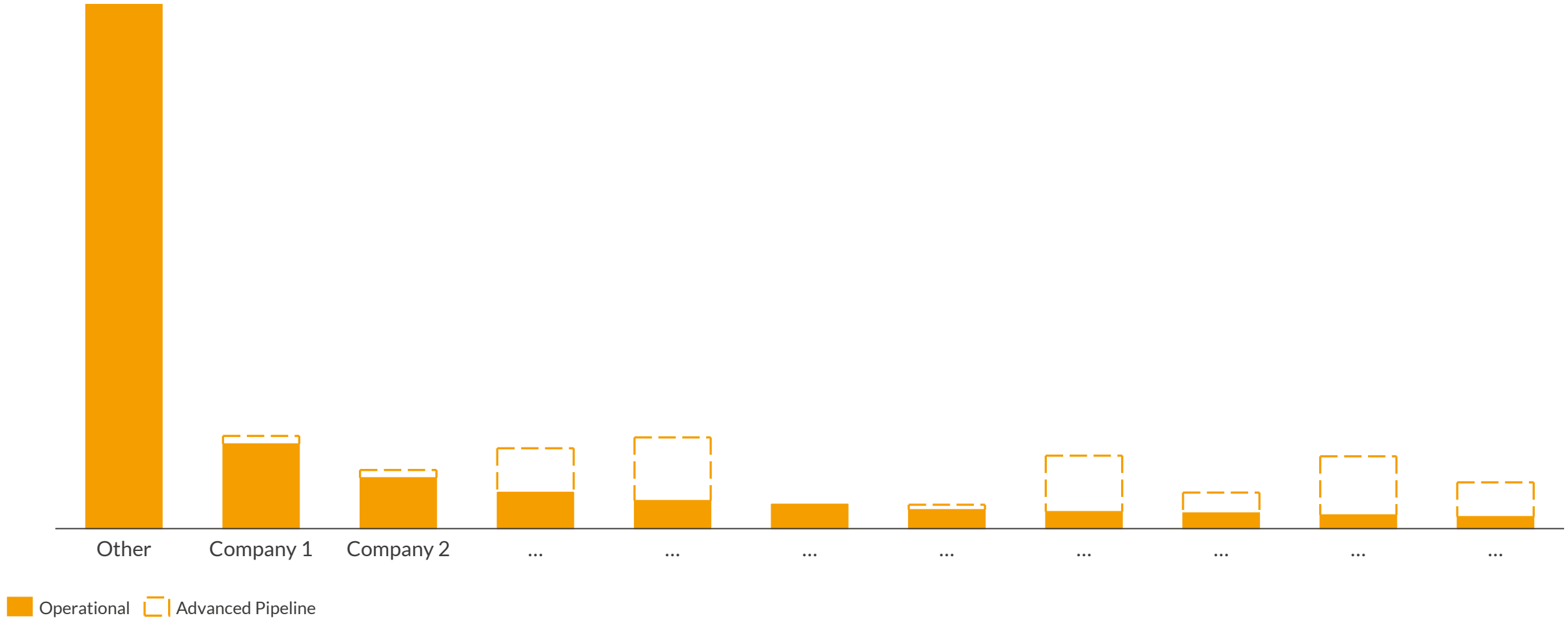
Battery capacity by leading energy storage developers/investors in Europe
GW



Sources: Aurora Energy Research, PV Magazine, Energy storage news, Renewables Now, Current news, GESDB

A growing number of battery suppliers, integrators and route-to-market providers are active in Europe as the BESS industry develops

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Battery suppliers and integrators

H1 2024 top 5 global market share of battery suppliers

%

2023 top 3 integrators in Europe by market share

%

Route-to-market providers

Examples of route-to-market providers across Europe

Active players in the UK	
Players in other moderately established markets	
Nascent markets	

Sources: Aurora Energy Research, SNE Research, Statista, Energy Storage News, Renewable Energy World

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Executive Summary

Policy and regulatory environment

1) National Energy and Climate Plans. 2) The Polish Energy Policy 2040 is a draft legislation with proposed targets. 3) Refers to Spain's PERTE ERHA call for co-located projects.

Source: Aurora Energy Research

[redacted] sees the most attractive policy environment for grid-scale battery deployment, followed by [redacted]

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Policy environment

Countries are assessed in terms of their policy environment for battery storage as of Q1 2025, based four criteria shown below. An overall score between 0-10 is assigned for each country reflecting the following weighting of assessment criteria.

Metric	Weighting	Rationale
4 Availability and contractability of revenue streams	*30%*	Indicates availability and long term contractability of revenues
5 Renewables targets (i.e. driver of flexibility needs)	*30%*	Demonstrates policy ambition for renewables deployment
6 Risks from grid connection and charges	*30%*	Indicates regulatory risks around grid connection and charges
7 Competition risks	*10%*	Indicates competition risks around aggregation, electrolysers and EVs

Rank	Region
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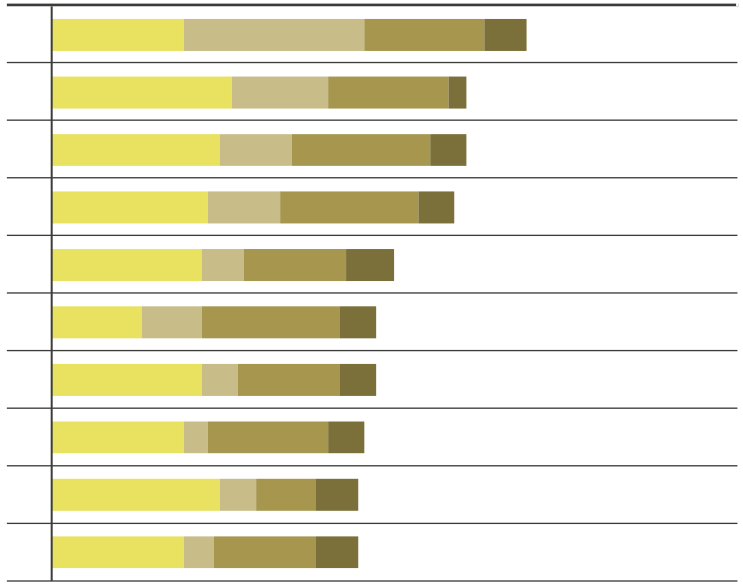

Source: Aurora Energy Research

The outlook for battery storage deployment is driven by four crucial policy related factors

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	A Availability and stack-ability of revenue streams	B Emissions and Renewables policies	C Regulatory challenges and opportunities	D Policy strategies and targets for battery storage
Description	▪ Indicates the availability of diverse revenue streams ▪ Highlights the stack-ability of the revenues streams as enabled by policy and regulation	▪ Country targets for variable renewables buildout influences the evolution of flexibility needs on the system and thus opportunities for batteries. ▪ Policy ambition around phasing out thermal capacity which are conventional providers of firm capacity and system services also influences system flexibility needs	▪ Permitting and grid connection rules for battery assets have a significant impact on deployment, clear and long-term regulatory framework required. ▪ Regulation around aggregation of distributed assets plays a key role in the deployment of battery storage.	▪ Country policies regarding energy storage shape the development of their systems and influences buildout. ▪ It indicates government support and commitments to capacity deployment
Implications	▪ Ancillary services in a country and the ability of battery storage assets to participate is a key driver of buildout. ▪ Different capacity mechanisms are in place across Europe where batteries are allowed to participate with a derating factor creating additional revenue.	▪ High buildout of variable renewables necessitates the buildout of flexible capacities including battery storage. ▪ Phase out of thermal generation capacity creates a deficit in firm capacity and grid services resulting in a higher requirement for low carbon flexible capacities including battery storage.	▪ Availability of grid connections and reasonable charges serve as one less barrier for battery storage assets. ▪ Aggregated distributed assets create a sizeable capacity that becomes eligible to trade in participating power markets, competing with grid scale batteries.	▪ Establishing policies, strategies and targets for energy storage deployment drives investor confidence. ▪ Clear policy in support of flexible assets results in greater buildout of these assets.

Source: Aurora Energy Research

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Grid scale battery storage assets typically participate in up to four types of markets, with further access to additional ancillary services

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Response time

A Delivery

Years | Hours | Minutes | Seconds

CM Capacity Market

- Ensures security of supply by procuring a sufficient level of firm capacity to meet peak electricity demand
- Contracts are awarded either one or four years in advance for lengths of 1-15 years
- Payments are typically made on a capacity basis in kW/year and de-rated based on contribution to security of supply
- Although typically heavily derated, batteries can take advantage of the additional revenues without impacts to degradation

WM Wholesale & Intraday Markets

- The day-ahead market provides a platform to buy and sell power to meet demand every hour
- The intraday market procures continuous trading during the day
- Contracted from years ahead to T-1 hour trading
- Batteries can take advantage of arbitrage opportunities on both the day-ahead and the intraday markets

BS Balancing and Restoration Services

- Balancing markets and slower frequency response services (e.g. mFRR and Replacement Reserve) maintain system balance in each daily trading period and often require higher, longer-lasting energy
- Batteries can capitalize on these services through arbitrage and revenue opportunities

FR Frequency Response Services

- Maintains operational grid requirements and provides fast-acting power injection to arrest fast changes in system frequency, through sub-second to minutes long response
- Mostly procured on a capacity basis day ahead (e.g. FCR) or otherwise contracted in advance
- Batteries can gain revenues from the provision of frequency services

OS Other ancillary services and benefits

- Additional trading markets exist to procure non-frequency ancillary services to maintain grid operability such as inertia and local congestion mitigation services, which creates additional revenue opportunities for batteries
- Grid charge credits or avoidance in specific countries could potentially provide additional benefits for batteries

Sources: Aurora Energy Research, BEIS, National Grid, Ofgem

Most countries allow for batteries to stack various revenue streams, however contractual revenues are limited (1/3)

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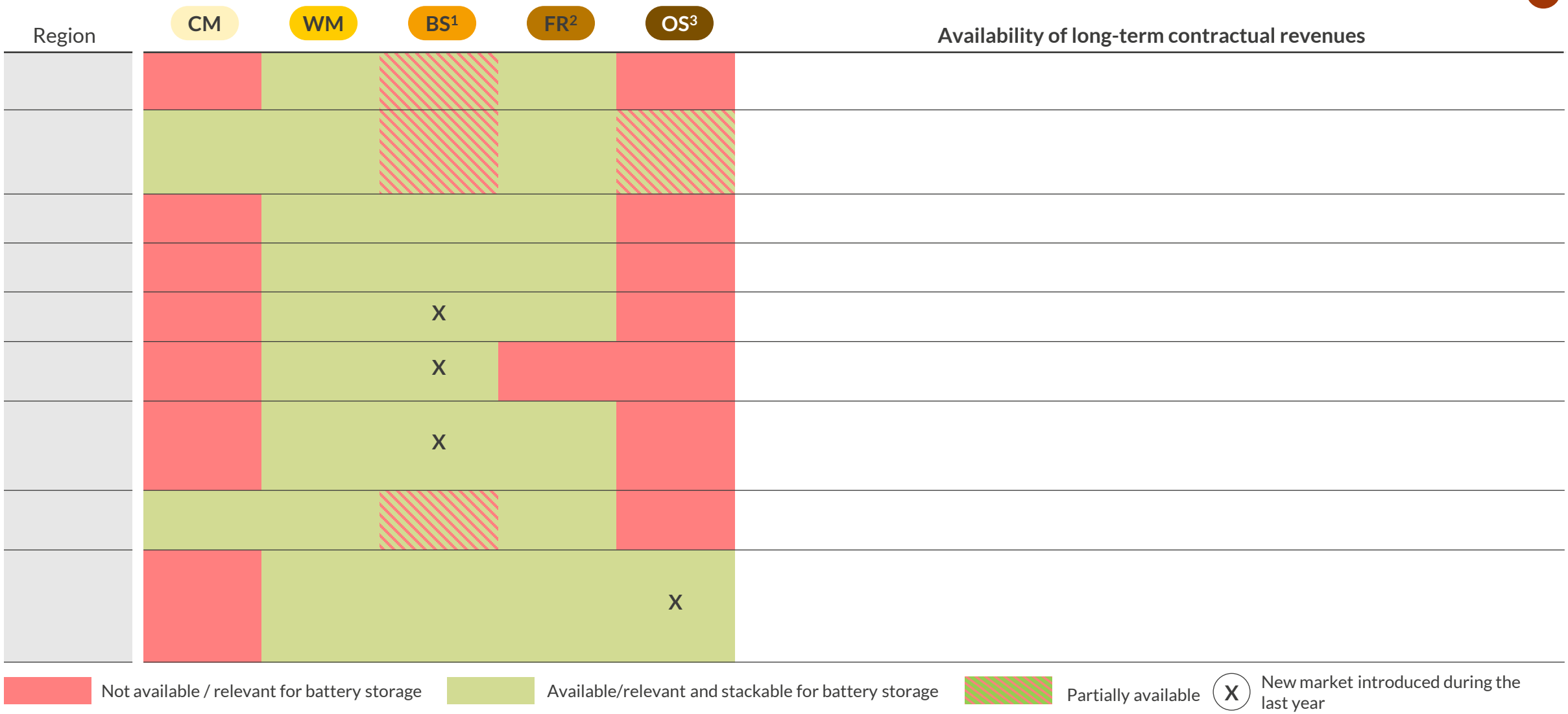

Most countries allow for batteries to stack various revenue streams, however contractual revenues are limited (2/3)

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A

Most countries allow for batteries to stack various revenue streams, however contractual revenues are limited (3/3)

AURORA

A

The addition of new revenue streams is discussed across Europe - especially capacity markets can be an attractive addition for batteries

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Revenue stream	Country	Comment
CM		
BS[1]		
FR[2]		
OS[3]		

Frequency and other balancing services across Europe are generally fragmented and reflect nationally-determined technical requirements (1/2)

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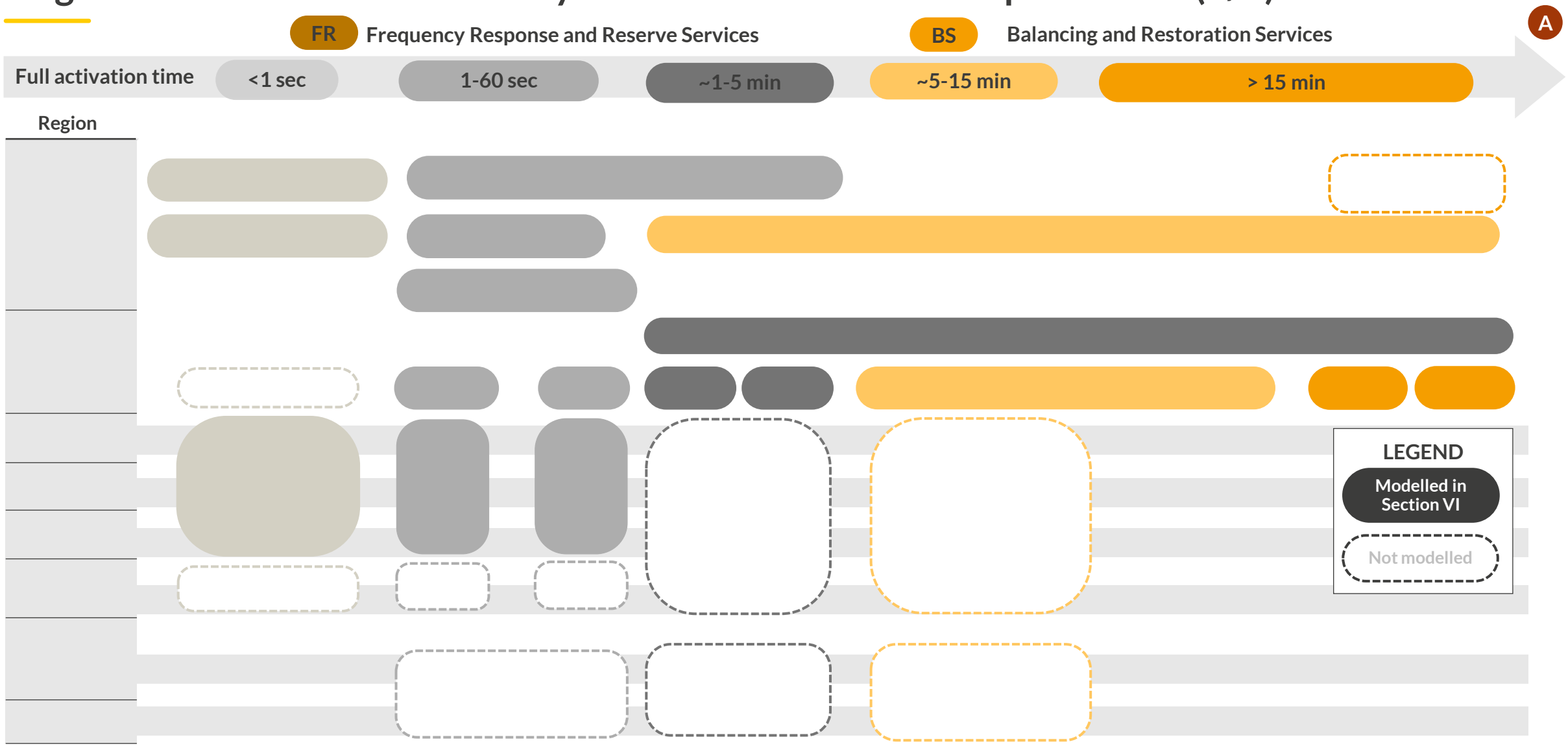

Sources: Aurora Energy Research, NESO, Bundesnetzagentur, Elia, ENTSO-E, Regelleistung.net, TenneT, Fingrid, SvK, Stattnet, Energienet

Frequency and other balancing services across Europe are generally fragmented and reflect nationally-determined technical requirements (2/2)

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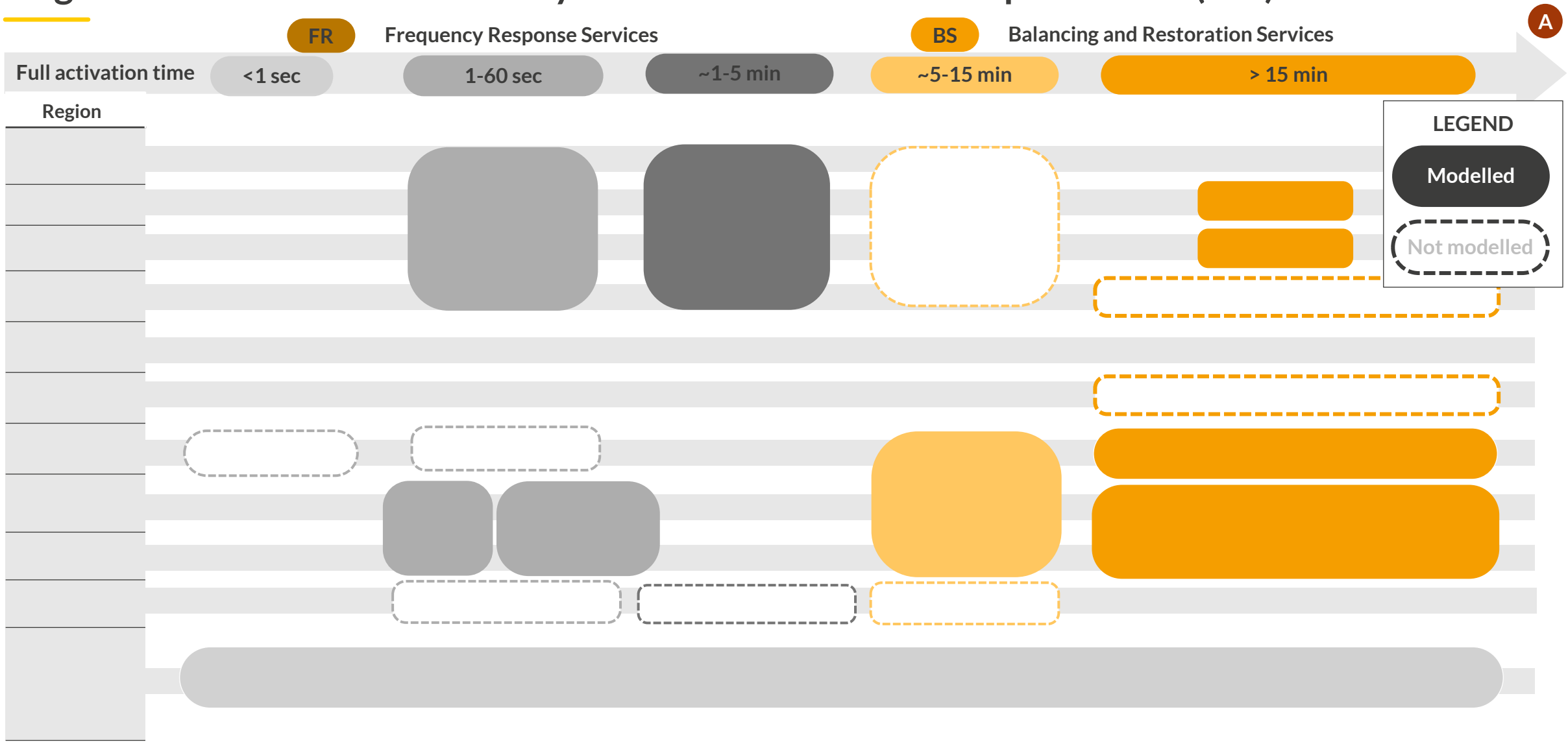

Sources: Aurora Energy Research, Bundesnetzagentur, Elia, ENTSO-E, Regelleistung.net, TenneT

Battery competitiveness is impacted by market features such as product length and symmetry, but not by gate closure

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Market feature	Competitive advantage for batteries

Advantage for longer durations Advantage for shorter durations Advantage for batteries (duration-agnostic)

Source: Aurora Energy Research

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Across Europe, several countries have set ambitious renewables targets, with the EU itself targeting 1102GW of solar and wind by 2030

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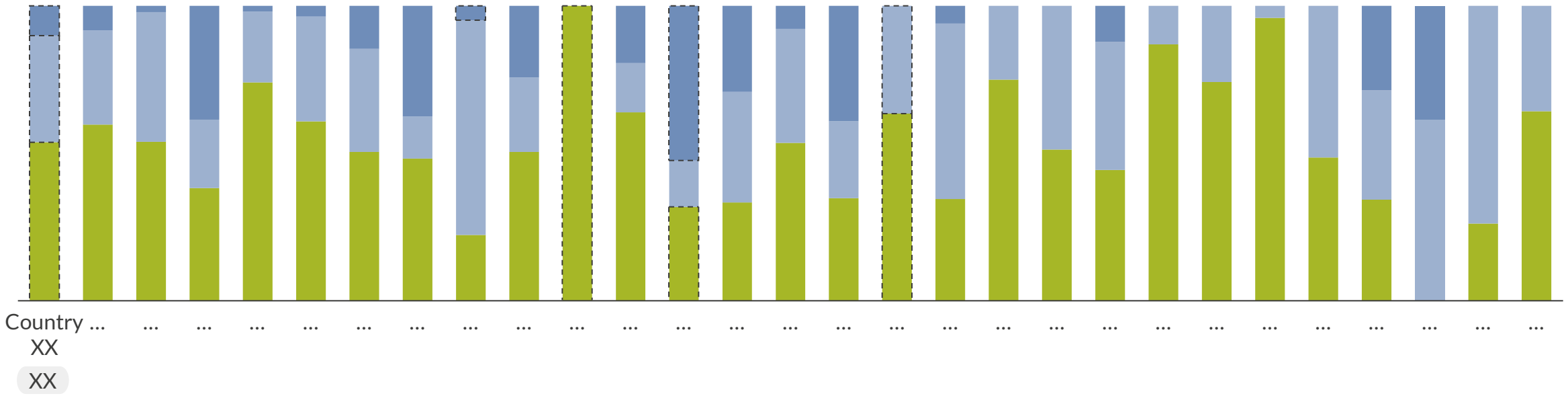
B

Target RES installed capacity by 2030
GW



Legislations for the phase-out of coal creates opportunities for batteries across Europe, while outlook for nuclear remains mixed

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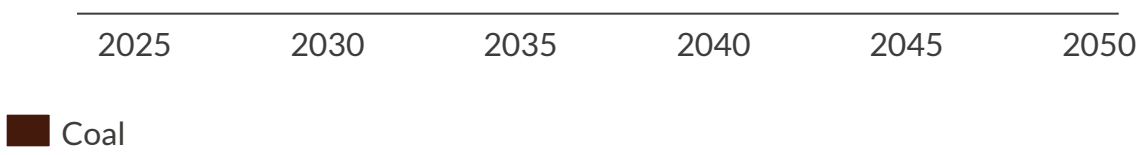
B

Coal capacity across Europe
GW



Nuclear capacity across Europe
GW

Sources: Aurora Energy Research, European Commission, RTE, Nordic TSO, NECP, National energy strategies

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A congested grid can lead to delayed grid connection and high fees, but congestion and grid-related policies can also booster profitability

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This report ranks markets in Europe for their ease of grid integration for grid-scale batteries, based on the following scoring criteria and an internal survey and calibration of views from Aurora's market leads.

Grid Connection score

1. **High difficulty**: limited grid availability being a major hurdle in the market and causing delays for new connections, high connection (upfront) costs
2. **Moderately challenging**: average connection times and costs for grid connection
3. **Relatively easy**: vast grid availability and quick connection approvals, special exemptions from grid tariffs

Grid usage fees and charges score

1. **Unfavourable**: high charges significantly dampening business case, double charging of fees
2. **Moderate**: average grid connection charges, no special exemptions but not double charged
3. **Favourable**: special exemptions from grid tariffs

Grid congestion revenues

1. **Unfavourable**: There is no monetary or regulatory incentive to provide local flexibility
2. **Moderate**: There is a monetary incentive to provide local flexibility, but it is neglectable in the business case **OR** providing local flexibility is not incentivised monetary, but it provides other benefits (e.g. faster grid connection)
3. **Favourable**: Revenues from congestion management are a significant part of the revenue stack in some business cases (min 10%)

Grid Integration score

Sources: Aurora Energy Research

Grid connection times tend to pose a significant hurdle to battery deployment, with initiatives being taken to reduce the wait

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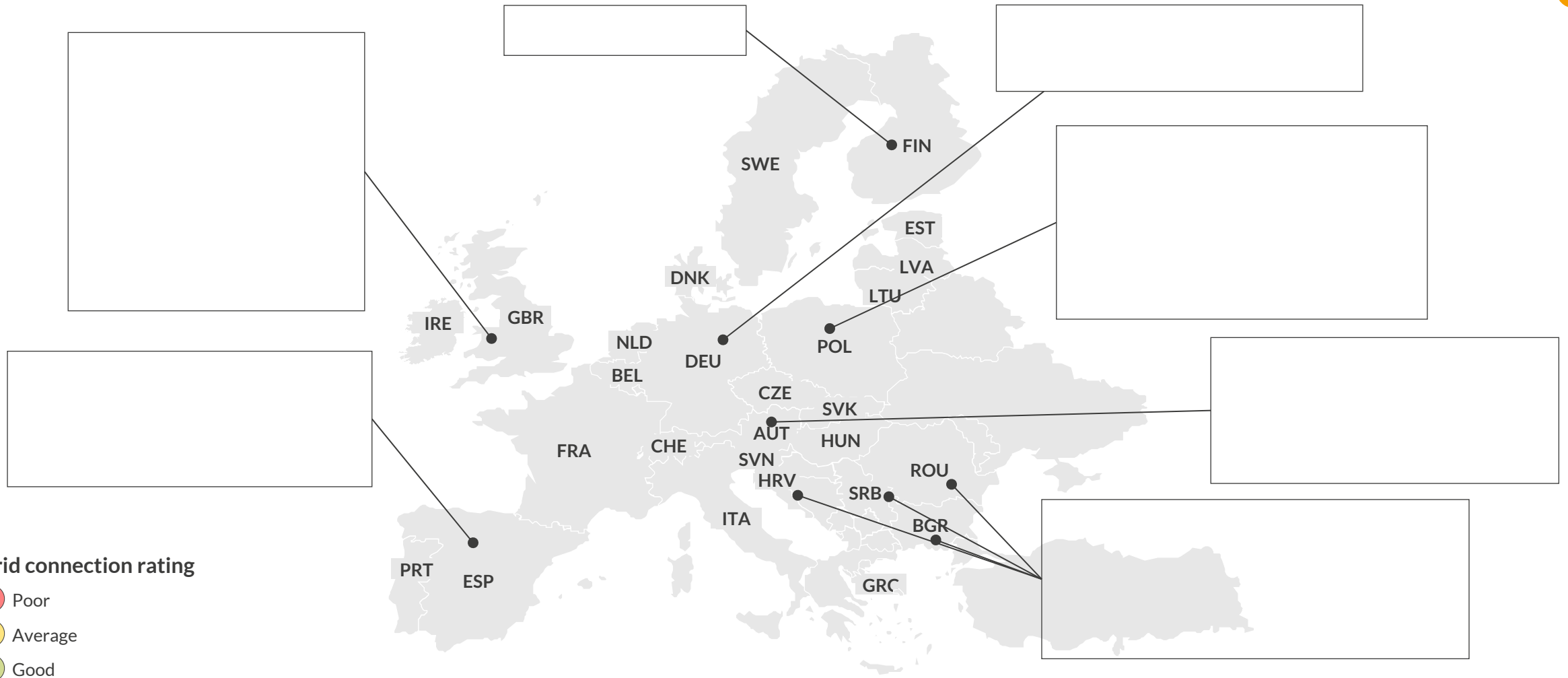

Sources: Aurora Energy Research

[redacted] and [redacted] see attractive grid charge and congestion revenue policy, whereas high fees in Hungary and Ireland deter BESS buildout

Grid Usage and Charges	Congestion Revenues: None present	Congestion Revenues: Neglectable revenues / not incentivised monetarily	Congestion Revenues: Significant portion of revenue stack
Special exemption from grid tariffs	[redacted]	[redacted]	[redacted]
Average grid connection charges	[redacted]	[redacted]	[redacted]
High charges / double charging of fees	[redacted]	[redacted]	[redacted]

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- [redacted]
- [redacted]
- [redacted]

Sources: Aurora Energy Research, Ofgem

New competitive risk for batteries arises from supportive policies on demand-side and BtM aggregation, electrolysers, electric vehicles and RES participation

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This report ranks markets in Europe for their competitive risks from competing flexible technologies to grid-scale storage, assessed based on policy support[1] and regulatory access to wholesale or flexibility markets for competitive technologies.

Demand-side response and BtM aggregation

1. Strong policies in place allowing aggregation of BtM and/or demand side response
2. Upcoming measures planned allowing aggregation of BtM and/or demand side response
3. No specific measures allowing aggregation of BtM and/or demand side response, or temporary trials in place with no permanent policy announced

H_2 Electrolysers

1. Strong supportive policies for hydrogen in place; electrolysers can charge from the grid and participation in flexibility markets is allowed
2. Some policy support in place or upcoming policy support for electrolysers is planned or in discussion; electrolysers face some restricted access to grid charging and/or flexibility market access
3. No specific policies or measures planned

Electric vehicles

1. Strong measures in place incentivising EV adoption and clear policy for aggregation of flexible EVs into wholesale and flexibility markets
2. Some policy support in place or measures planned for EV adoption; discussion ongoing in policy allowing aggregation of flexible EVs in wholesale and flexibility markets
3. No specific measures for EV adoption, no market access for wholesale or flexibility

RES participation

1. Renewables are allowed to participate in ancillary services and balancing and are already actively doing so
2. Renewables are not forbidden to participate in balancing, but market rules make it very difficult
3. Renewables are not allowed to participate in balancing

Competition risk

Traffic Light Score Legend

1-4	**High** risk
5-8	**Medium** risk
9-12	**Low** risk

1) The competitive risk metric considers only policies and regulations favouring or hindering the rise of competitive flexibility assets, but it does not consider their market share.

Sources: Aurora Energy Research

[redacted] sees the highest competitive risk from new technologies, where high electrolyser, EV & RES aggregation is expected

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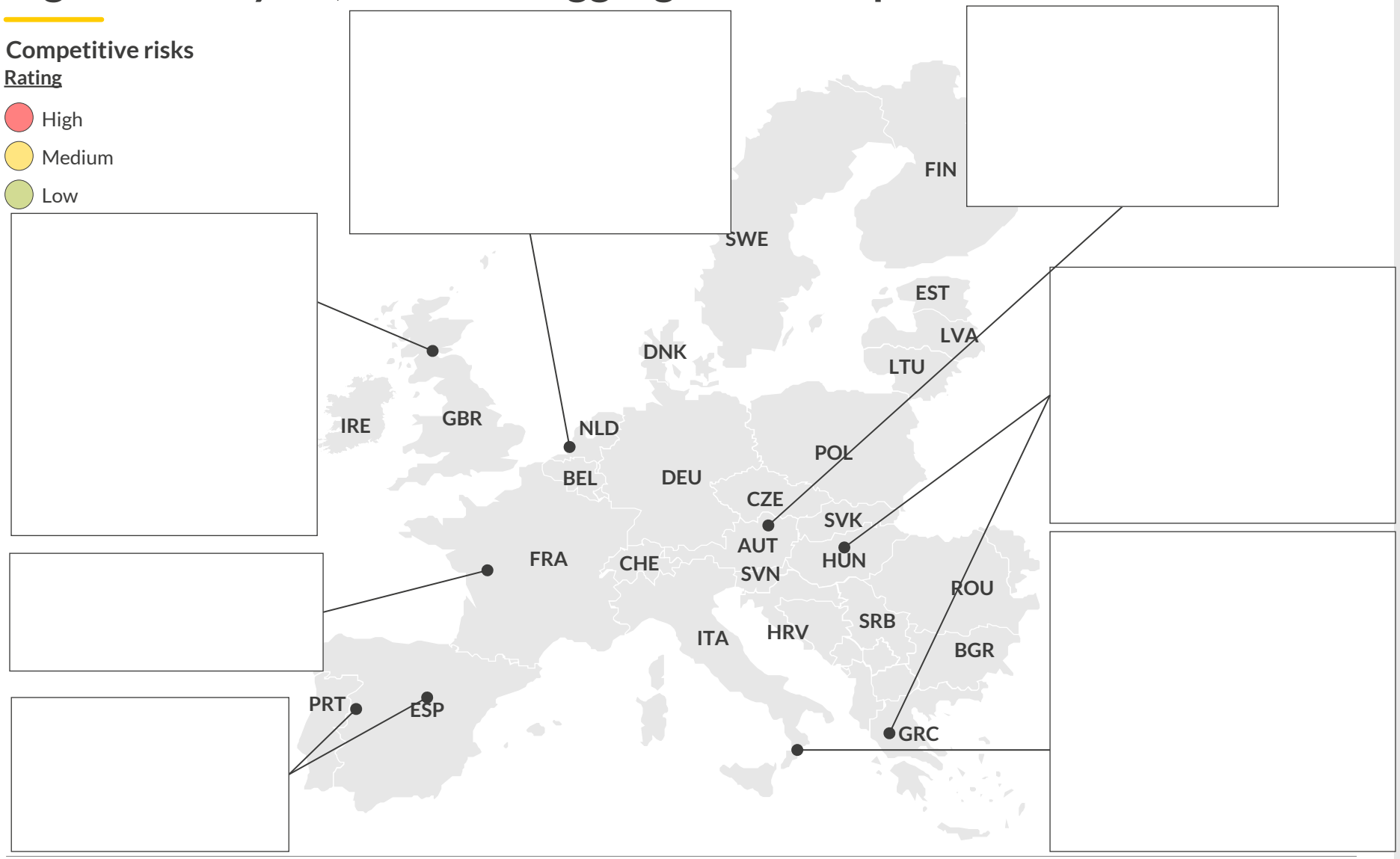
Competitive risks

Rating

- High
- Medium
- Low



Ongoing regulatory developments within certain markets present both opportunities and challenges for battery assets (1/3)

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Region	Market development	Impact	Implication on battery storage outlook

Sources: Aurora Energy Research

Ongoing regulatory developments within certain markets present both opportunities and challenges for battery assets (2/3)

AURORA

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Region	Market development	Impact	Impact on battery storage outlook

1) Meccanismo di Approvvigionamento di Capacità di Stoccaggio Elettrico.2) Day Ahead System Services Auctions. 3) Layered Procurement Framework. 4) For up to 15% of hours in a year, for the purpose of congestion management.

Sources: Aurora Energy Research

Ongoing regulatory developments within certain markets present both opportunities and challenges for battery assets (3/3)

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Region	Market development	Impact	Impact on battery storage outlook

Sources: Aurora Energy Research

ACER decided on the inclusion of 15-minute products in the single Day-Ahead coupling market by mid 2025, aimed to enhance market flexibility

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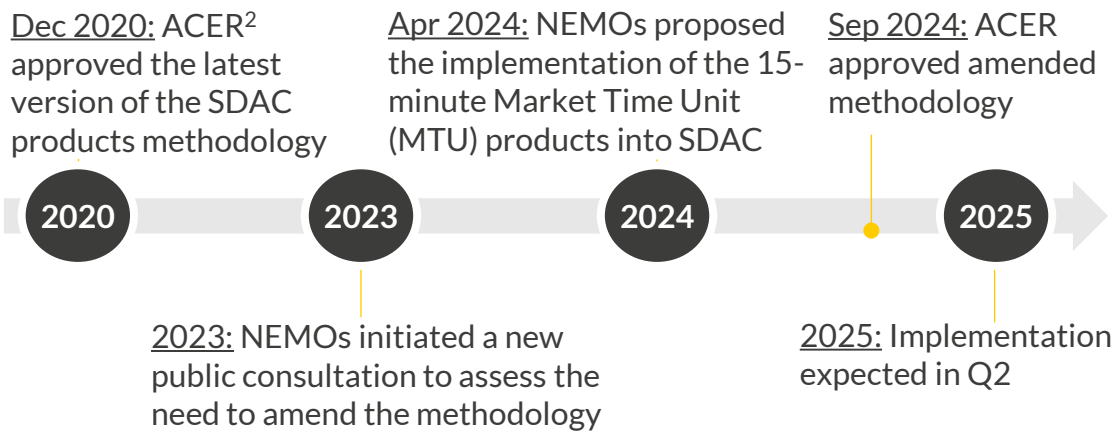
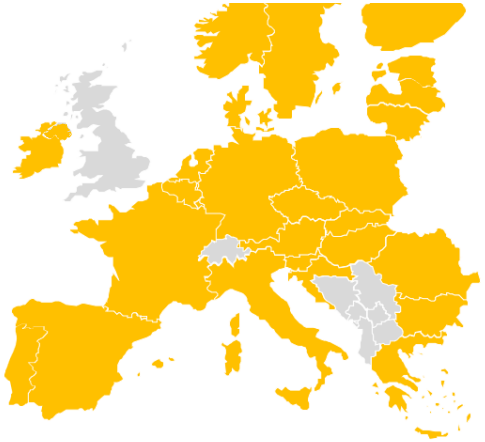
1 SDAC on the European level

- The goal of the SDAC[1] is to create a single pan European cross zonal Day-Ahead electricity market, promoting effective competition, increasing liquidity and enabling efficient utilisation of generation resources in Europe.
- SDAC allocates scarce cross-border transmission capacity in the most efficient way by coupling wholesale electricity markets from different regions through a common algorithm.
- The SDAC products methodology lists all products that are eligible for inclusion within the EU single Day-Ahead coupling.



2 SDAC amendment process

- Every two years, all NEMOs[3] are required to consult market participants, as well as all TSOs[4] and regulatory authorities, to review the current SDAC products available in the market and amend the list of products if required.
- In April 2024, NEMOs proposed an amendment of the SDAC products methodology to enable the implementation of the 15-minute Market Time Unit (MTU) products into the single Day-Ahead coupling, with approval made by ACER in September 2024. The amendment will:
  - Allow greater compliance with the EU Electricity Regulation
  - Enhance flexibility for market participants, allowing them to trade electricity for each 15 minutes in the SDAC, potentially enabling more sophisticated trading strategies and lowering imbalance volumes.



Sources: ACER, NEMO, National Grid, ENTSO-E

At the European Level, from mid 2025 onwards, 15-minute trading will be possible in the Day-Ahead market

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German Example: Illustrative Day-Ahead and Intraday auction prices
€/MWh

Sources: Aurora Energy Research, EPEX SPOT, ACER

Frequency Regulation Reserves will increasingly be coordinated at EU level between Member States, increasing cross-border competition

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Platforms	Target Services	Implementation status	Implications

Sources: Aurora Energy Research, ENTSO-E

PICASSO is the European TSOs' initiative for automated aFRR energy exchange to boost grid stability and market integration

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Sources: Aurora Energy Research, Elia, ENTSO-E, Regelleistung.net, TenneT

The implications of future aFRR market alignment with PICASSO have mixed impacts on battery opportunities

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Factors	Description	Impact on battery economics
Size and volatility of markets 		
Availability of interconnectors 		
Granularity of bids (15 min) 		
Activation rate 		

Sources: Aurora Energy Research, ENTSO-E

While concerns about PICASSO's transparency and unpredictability, along with Italy's temporary suspension, prompted ACER to launch a public consultation… (1/2)

C

Unforeseen sharp spikes in Italian imbalance prices after joining PICASSO
1000€/MWh, highest and lowest imbalance prices in each month

Illustrative merit order curves of Italy and Austria; Terna's inelastic demand
Italian Imbalance prices of 3rd February 2024

Pricing, technical, and transparency issues in PICASSO led to Italy's temporary suspension and caused other countries to delay entry. ACER launched a public consultation in April 2024, where TSOs submitted their proposal to several of these issues. Following the consultation, ACER amended the balancing platform rules.

Sources: Aurora Energy Research, ENTSO-E, ARERA, ACER

…ACER amended the EU electricity balancing rules to address key challenges, including sharp price spikes experienced early 2024 in Italy's imbalance prices (2/2)

C

On 5th July 2024, ACER issued two decisions amending EU electricity balancing rules, following the public consultation earlier this year

ACER decisions 08-2024 and 09-2024 amends the following main points:

Key takeaway:

Impact example of introduction of price elastic aFRR demand available to TSOs
aFRR down bids, Italy and Austria combined merit order

Source: Aurora Energy Research, ENTSO-E, ACER

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Recent EU policy developments have bolstered battery storage support, creating new incentives and a more favourable environment for projects

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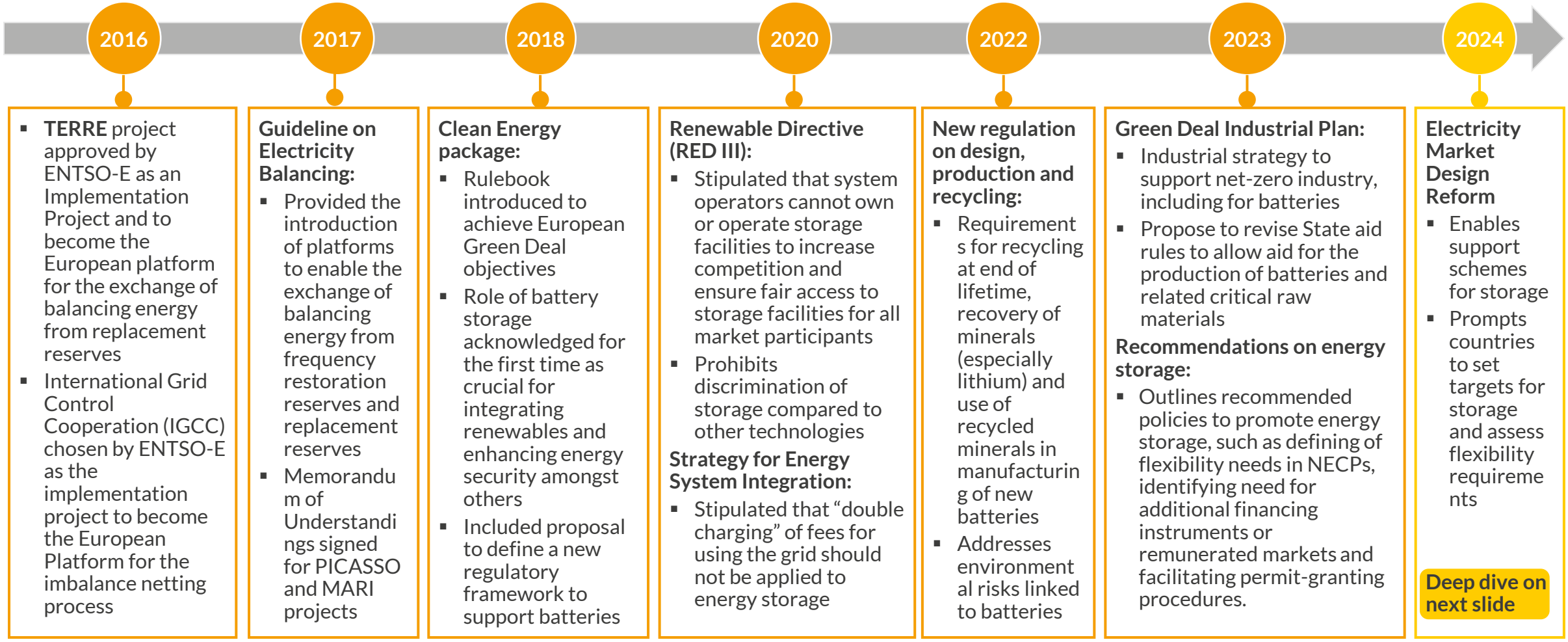

Sources: Aurora Energy Research, European Commission

The adoption of the Electricity Market Design reform has set more targeted objectives for Battery Storage, with several follow-up actions expected

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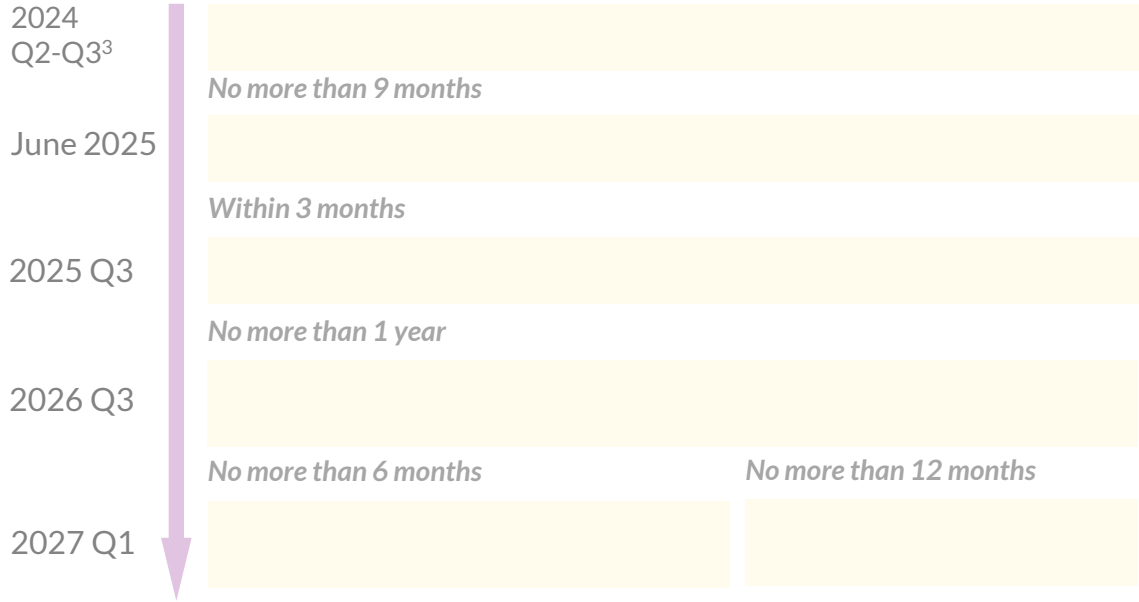
In April 2024, the Parliament of the European Union adopted the proposal to reform the electricity market design (EMD) regulation. The proposal aims to stabilize electricity prices and enhance consumer protection through regulatory measures. Detailed flexibility provisions are introduced.

Main flexibility provisions:

EMD reform and follow-up actions are expected within the next 2-3 years

Estimated action time



Key takeaways:

Source: Aurora Energy Research, European Parliament

Across Europe, a rising number of countries have introduced strategies and targets for energy storage deployment

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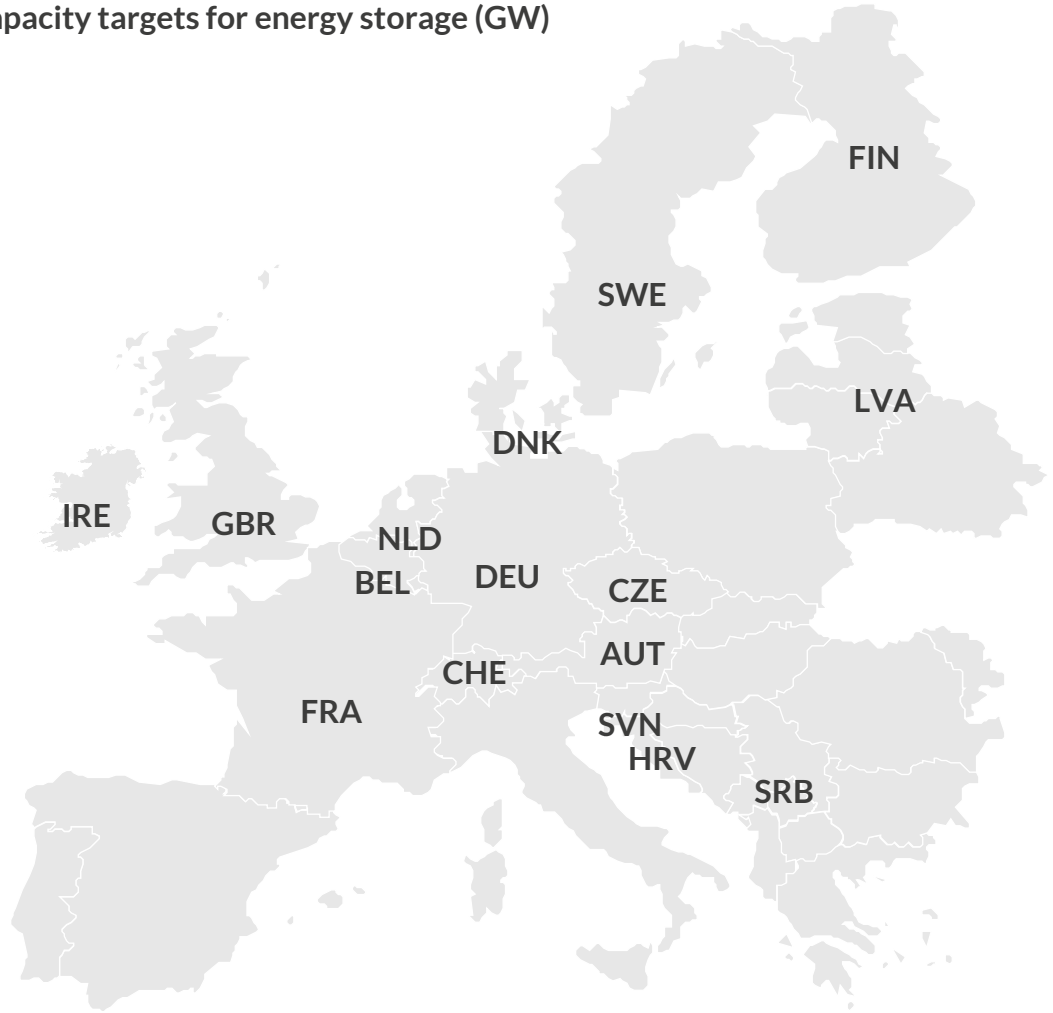
D

Capacity targets for energy storage (GW)



National government policies and targets for energy storage

Targeted battery auctions have subsidised at least [redacted] GW of BESS in [redacted], [redacted] and [redacted] with [redacted] GW in future procurement

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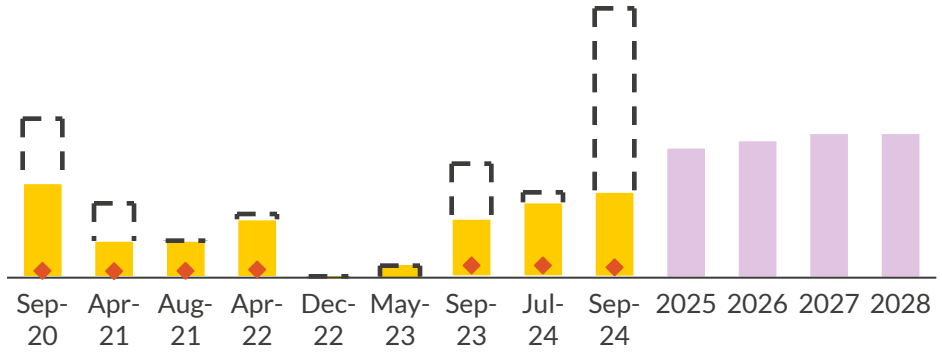
Germany: Innovation Auctions

Average accepted bid price, € /MWh nominal

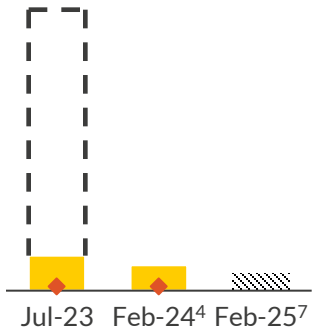
Capacity (RES+BESS) MW



Greece: National BESS auctions

Capacity, MW

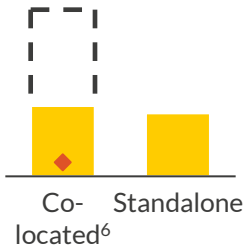
Average accepted bid price, €/MW/year



Spain: PERTE ERHA calls

Capacity MW

Average accepted bid price, 1000 € /MW



Call budget
Million €

Co-located[6]	Standalone
XX	XX

Italy's MACSE scheme aims to procure [redacted] GW of capacity by 2030; additional schemes have the potential to procure almost [redacted] GW

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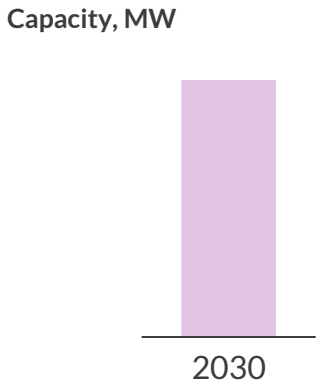
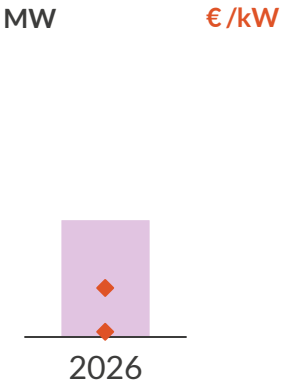
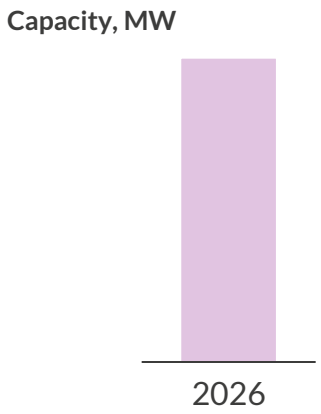
Italy: MACSE



Hungary: Storage CfD



Bulgaria: Co-located and Standalone storage grants



Romania: Battery storage state aid

Sources: Aurora Energy Research, European Commission

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Executive Summary

Revenue streams

Source: Aurora Energy Research

Ireland sees the most attractive revenue streams for battery storage, followed by Great Britain

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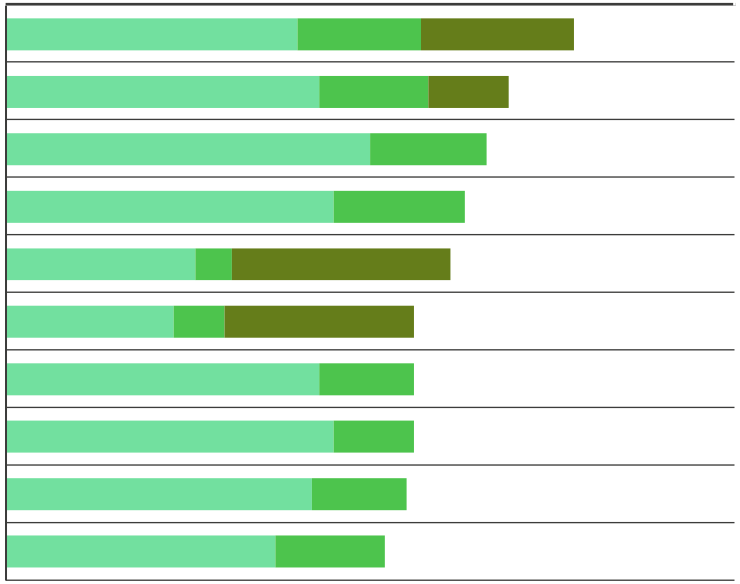
Revenue streams for battery storage

Countries are assessed in terms of their revenue streams for batteries between 2024-2030, based on three criteria shown below. An overall score between 0-10 is assigned for each country reflecting the following weighting of assessment criteria.

Metric	Weighting	Rationale
9 Average wholesale market daily spreads	*50%*	Indicates the value available from energy arbitrage in the wholesale market
10 Frequency and balancing markets saturation risk	*20%*	Assesses the risk of market saturation in frequency response and balancing services due to the deployment of other batteries. Higher risk leads to lower rating.
11 Capacity market revenues	*30%*	Indicates the value available from receiving capacity market payments

Rank	Region	Market attractiveness score
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		



Top markets

Average wholesale market daily spreads | Frequency and balancing markets saturation risk | Capacity Market revenues

Source: Aurora Energy Research

Energy arbitrage offers the most valuable margins for batteries in many European countries, followed by capacity payments for ancillary services

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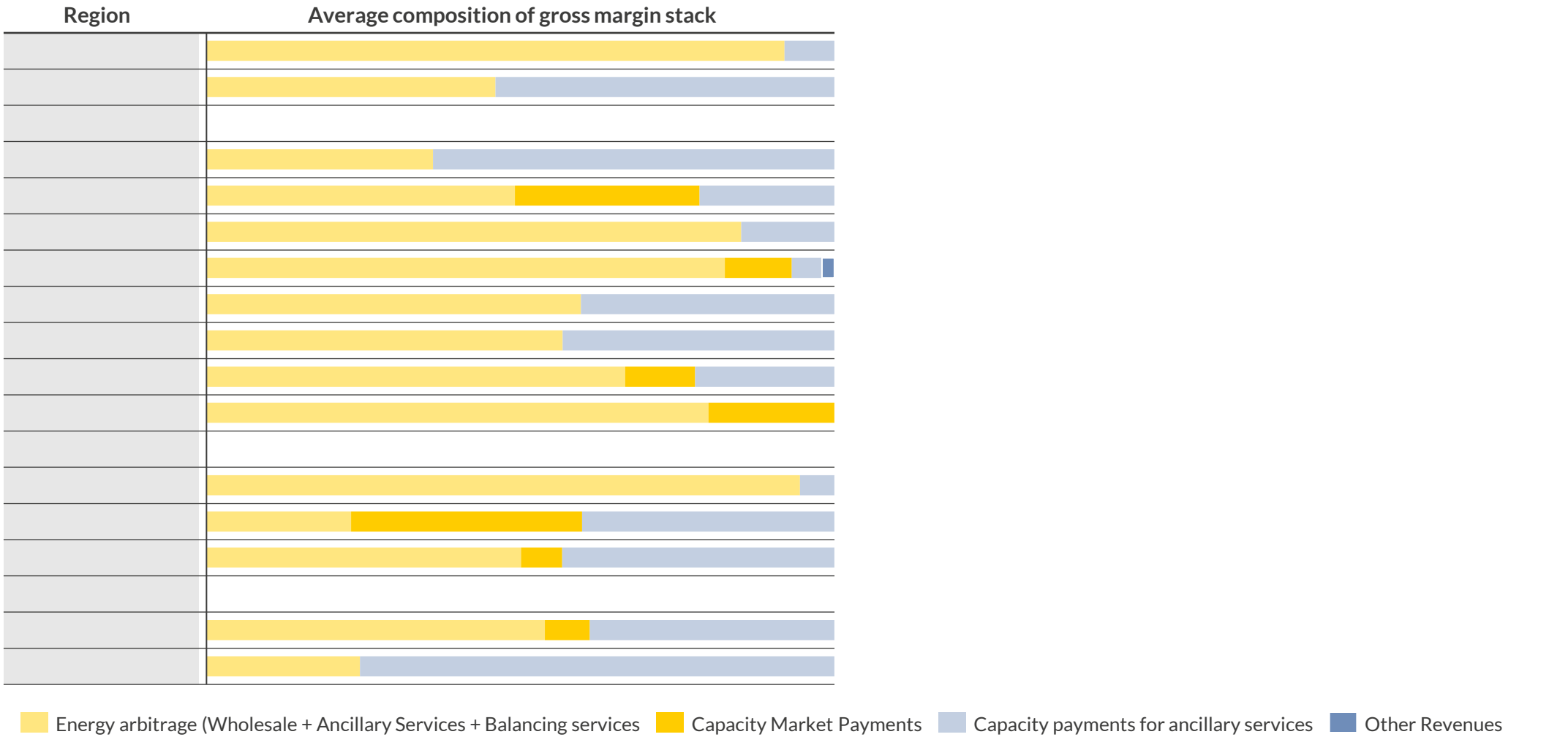
Summary of gross margin stack market composition

% of 2028 – 2042, 2h duration batteries



Source: Aurora Energy Research

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Battery expansion drives down market prices and transforms the landscape of ancillary services

Source: Aurora Energy Research

Installed battery capacity in 2024 is insufficient to saturate most Ancillary Services yet some, such as [redacted], come close…

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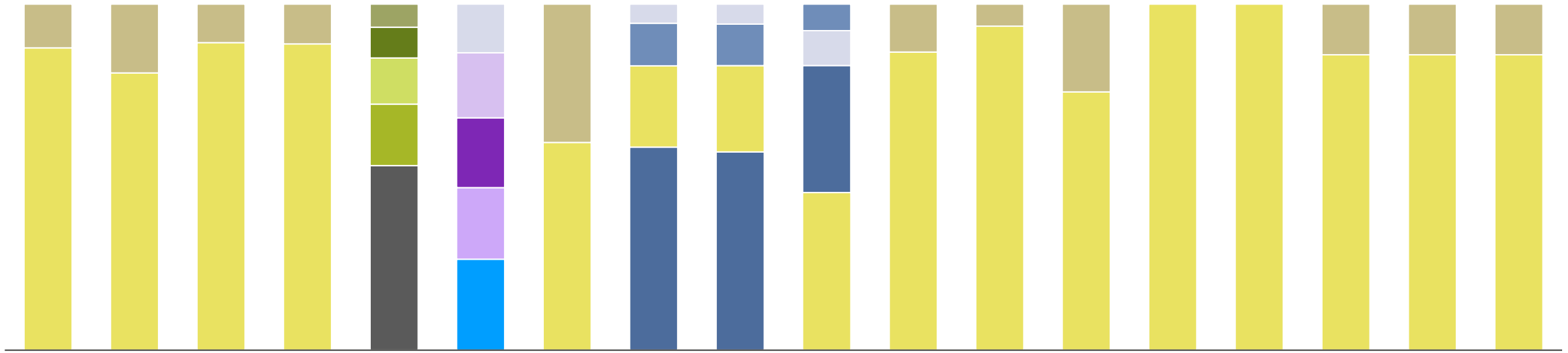
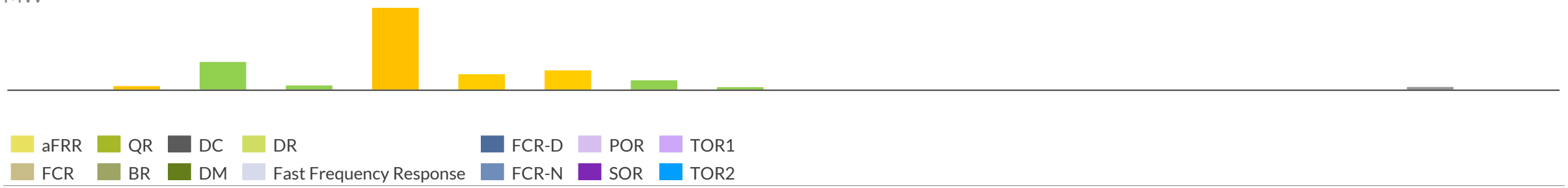
2024 Total Ancillary Service Procurement

MW



2024 Total Battery Capacity

MW



…but it will be sufficient to saturate by 2030 in most markets

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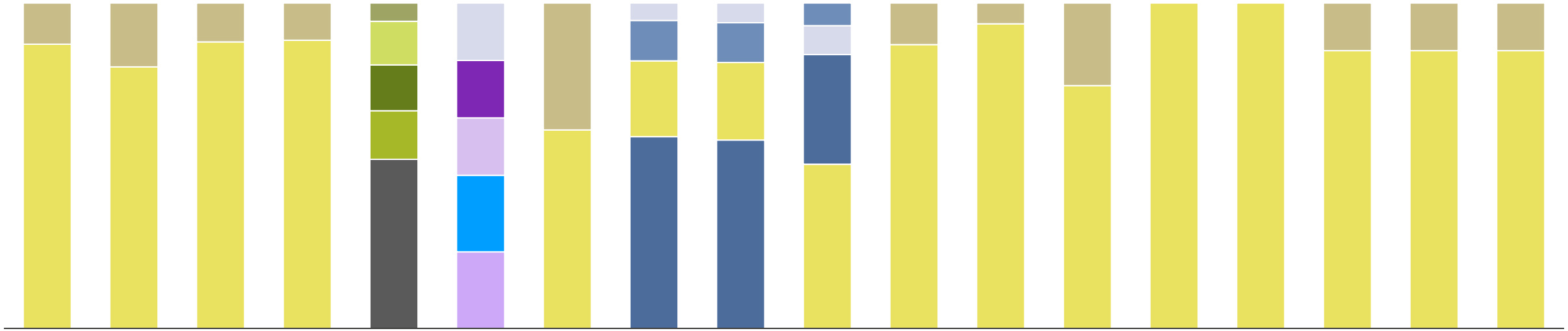
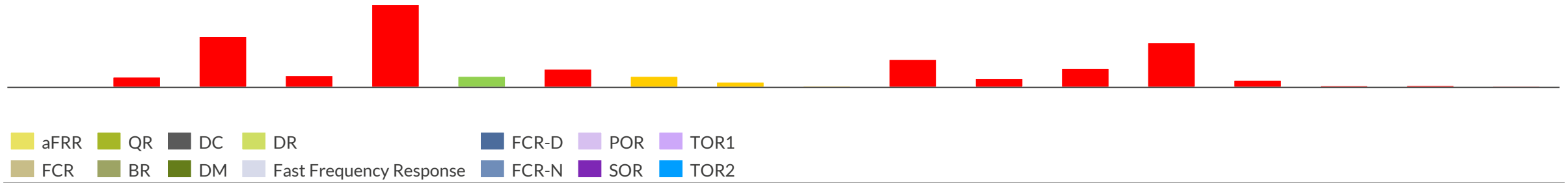
2030 Total Ancillary Service Procurement

MW



2030 Total Battery Capacity

MW



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Batteries are likely to face more Ancillary Services saturation, but Balancing Markets may present an opportunity

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A higher volume of balancing services is procured compared to ancillary services, making it more robust again cannibalisation

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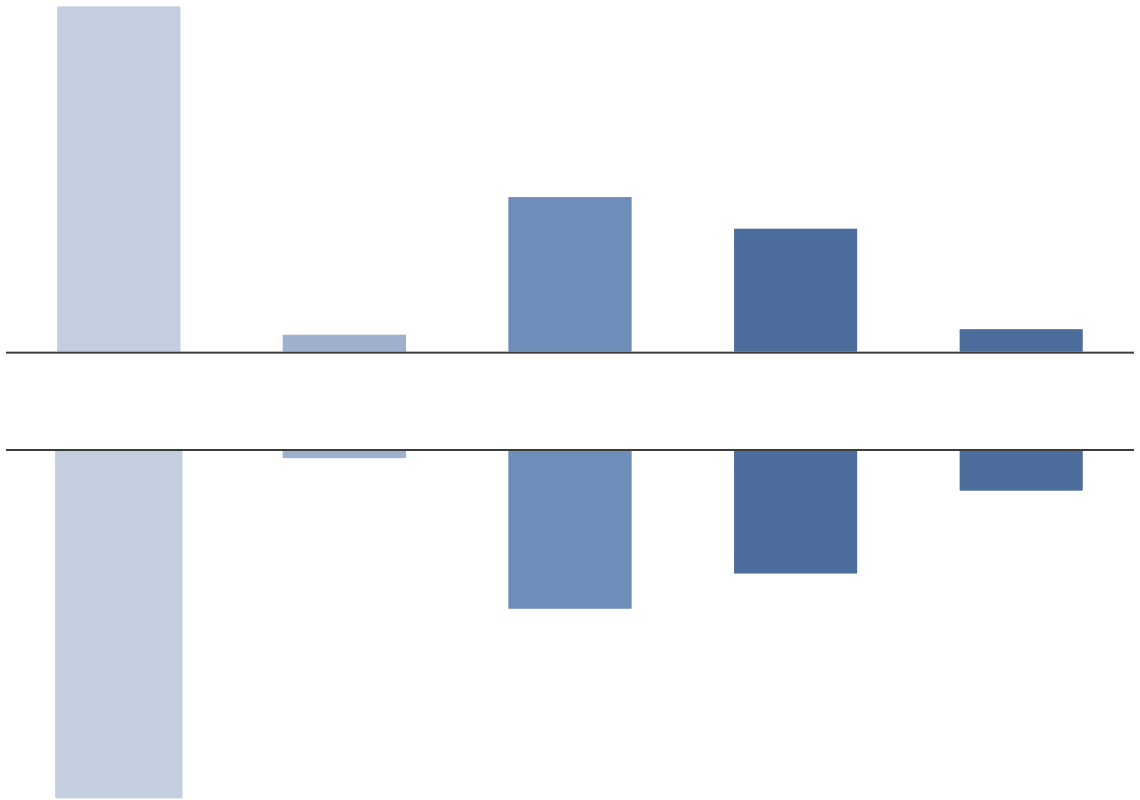
Market description

Region	Balancing and Restoration Services
	xx%
	xx%
	xx%
	xx%
	xx%
	Size relative to wholesale market, % xx%

Total accepted volumes Up/Down services in 2023

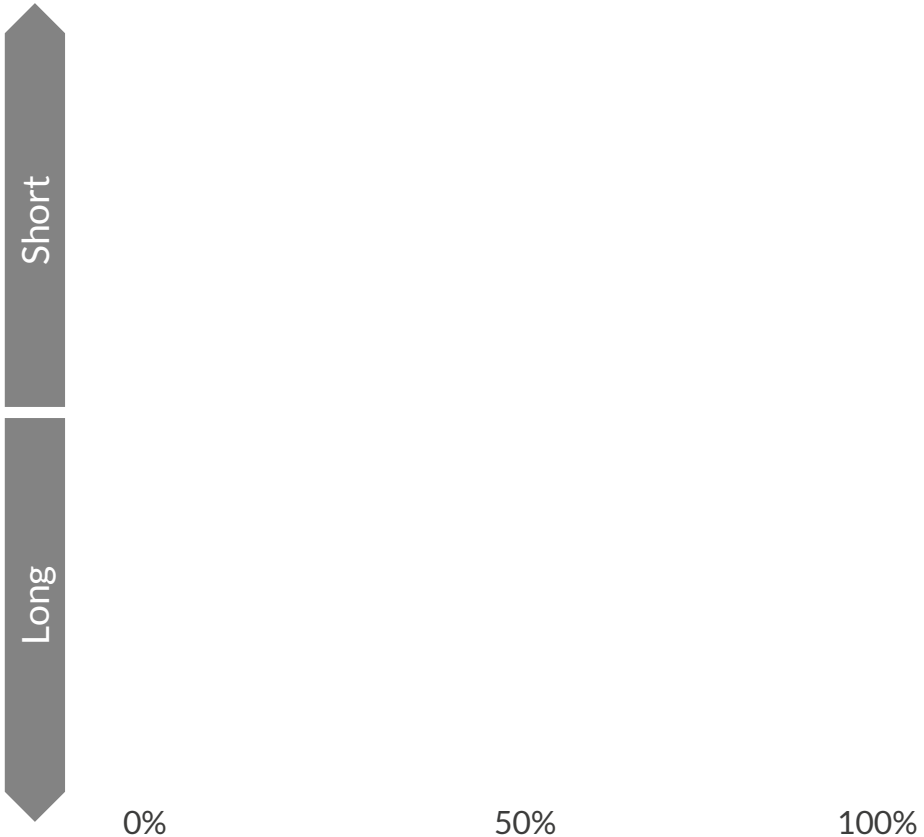
GWh



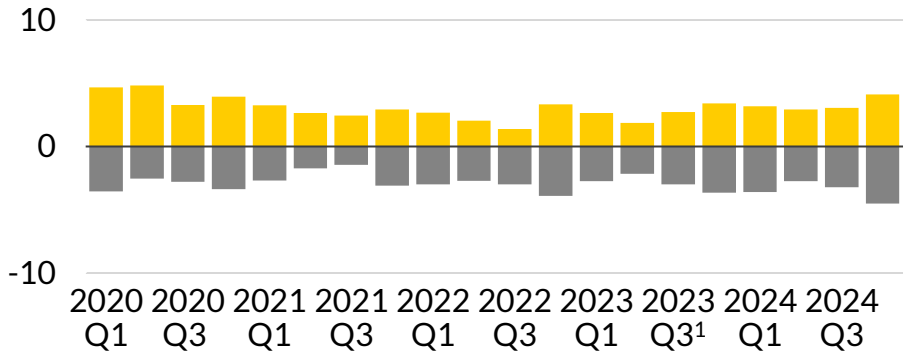
Sources: Aurora Energy Research, OMIE, Redes Energéticas Nacionais, Ofgem, Elexon, EirGrid, SONI

While demand for balancing and restoration services will increase due to increasing demand and variable renewables generation…

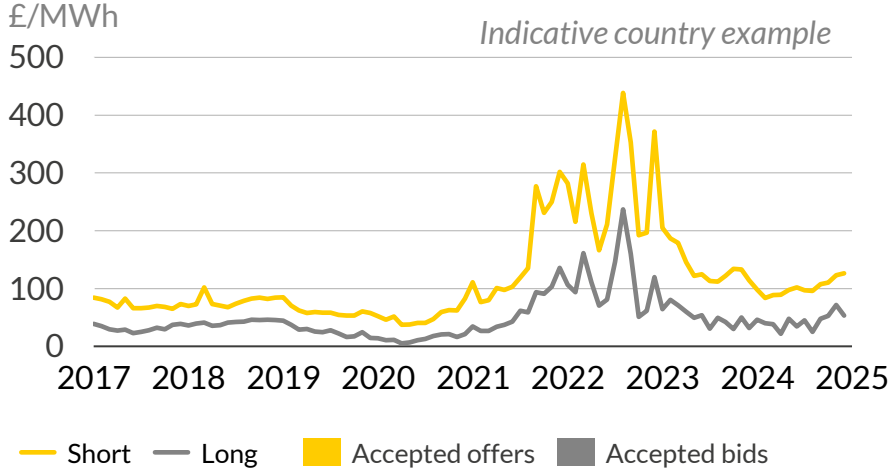
Net imbalance volume duration curve in Great Britain
Half-hourly, GWh



Historical balancing volumes in Great Britain
TWh



Historical average monthly system prices in Great Britain
£/MWh



- Net Imbalance Volume (NIV) is the volume of the overall system energy imbalance where the short volume indicates insufficient generation and long volume indicates excess generation.
- Long and short imbalance volumes are expected to increase over time due to high deployment of variable wind and solar generation.
- This increase in short and long volumes consequently drives increased demand for upwards and downwards energy balancing.
- As seen in the example of Great Britain, net imbalance volumes could increase by an additional 272% during peak hours when the system is short.
- This increase in imbalance volumes creates opportunities for batteries to provide the required balancing services.

Source: Aurora Energy Research

…prices for such balancing services are expected to adjust as the technology mix changes in each country (1/2)

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	Energy remuneration of selected Up services	Comments
Great Britain £/MWh (real 2023)		
Ireland €/MWh (real 2023)		

Source: Aurora Energy Research

…prices for such balancing services are expected to adjust as the technology mix changes in each country (2/2)

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	Energy renumeration of selected services, €/MWh (real 2023)	**Comments**
Italy		
Iberia		
Poland		

Source: Aurora Energy Research

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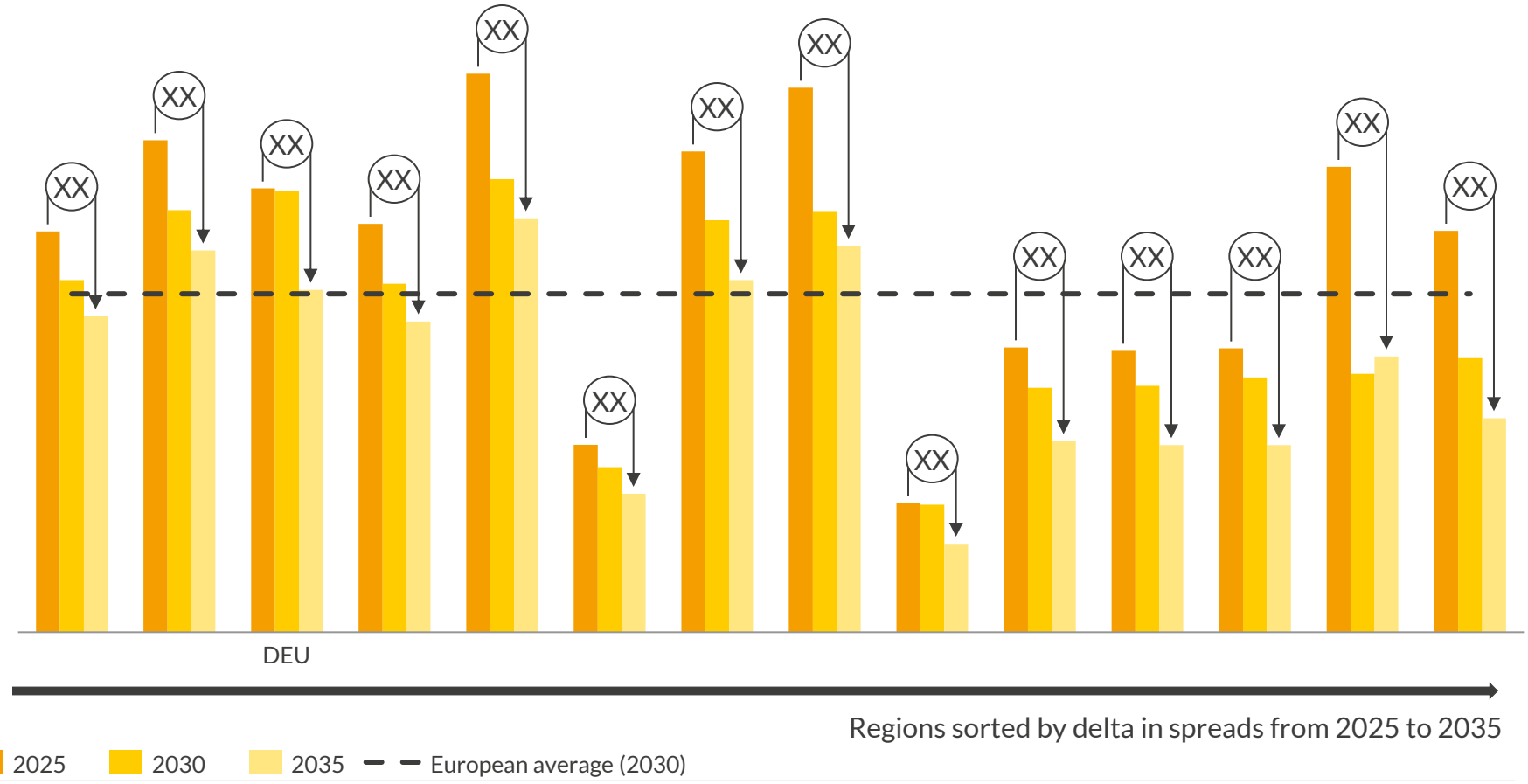
Most European regions see flexible buildout eclipse renewables growth, putting downwards pressure on spreads (1/2)

Average daily 1h wholesale day-ahead market price spread
€/MWh (real 2023)



Source: Aurora Energy Research

While spreads are expected to decrease on average, extreme weather events can lead to higher spreads compared to Aurora Central

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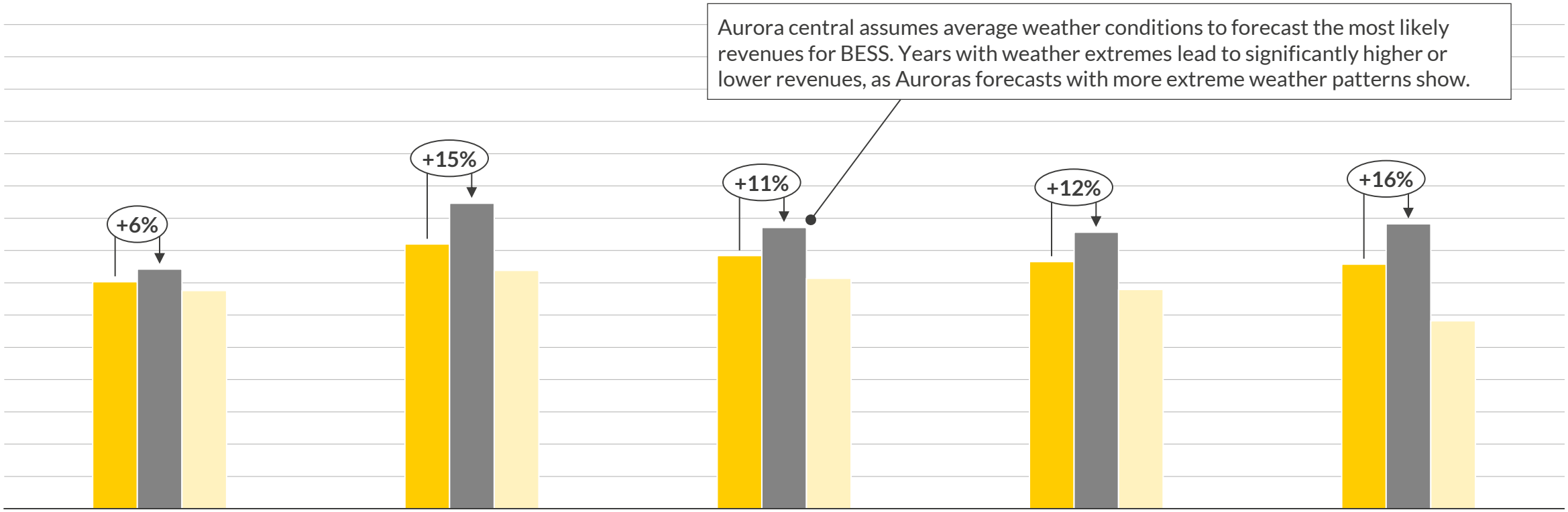
Average daily 1h wholesale day-ahead market price spread in 2030
€/MWh (real 2023)



Weather conditions can impact battery revenues: When low temperatures and high demand are combined with lower renewable load factors, wholesale prices can spike, widening spreads and providing arbitrage opportunities for battery storage beyond Aurora Central assumptions.

Aurora Central | High volatility weather year | Low volatility weather year

In Southeastern Europe, an extreme heatwave led to this region having the highest spreads in 2024 within Europe

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Intra-day markets generally offer up to % higher daily spreads compared to day-ahead, creating greater arbitrage opportunity for batteries

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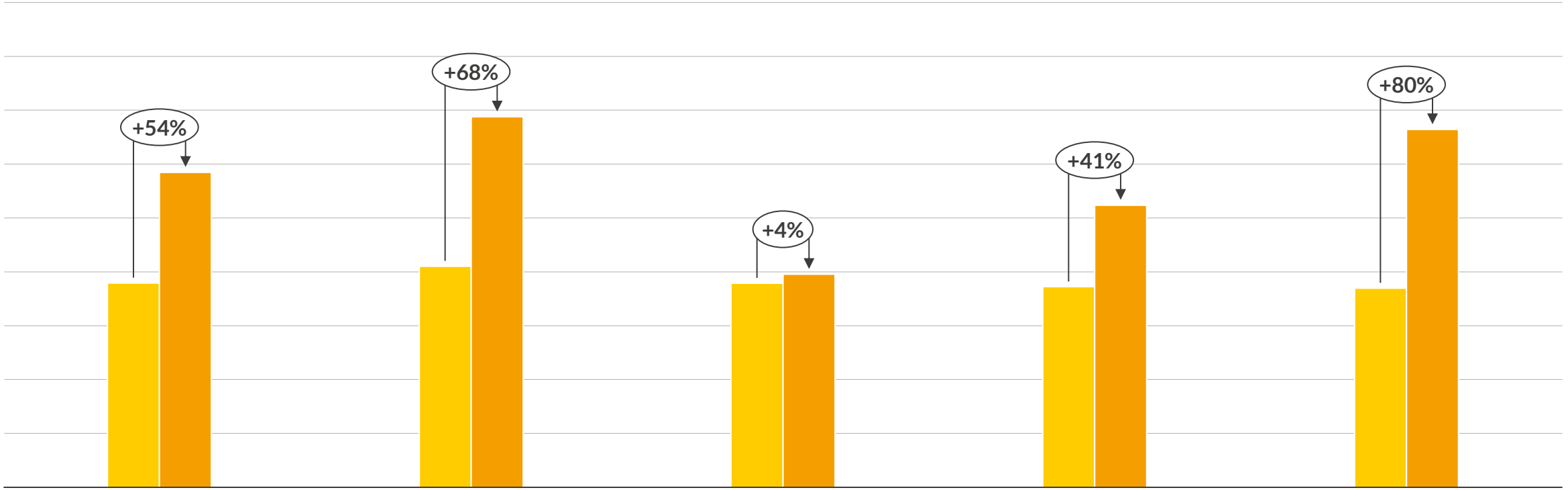
Average daily 1h wholesale day-ahead vs. intra-day market price spread in 2030
€/MWh (real 2023)



Intra-day spreads are typically higher than day-ahead spreads due to the proximity to delivery times and scarcity, presenting greater opportunity for battery energy arbitrage.

Day-ahead daily spread Intra-day daily spread

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Capacity Markets ensure security of supply standards are fulfilled by paying generators for capacity, rather than for energy alone

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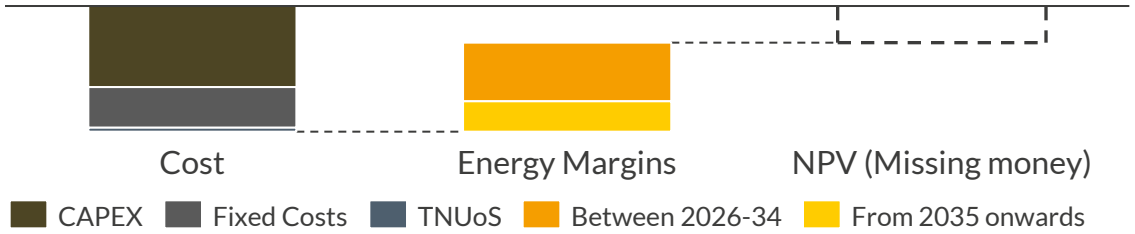
Why is a Capacity Market used in most countries?

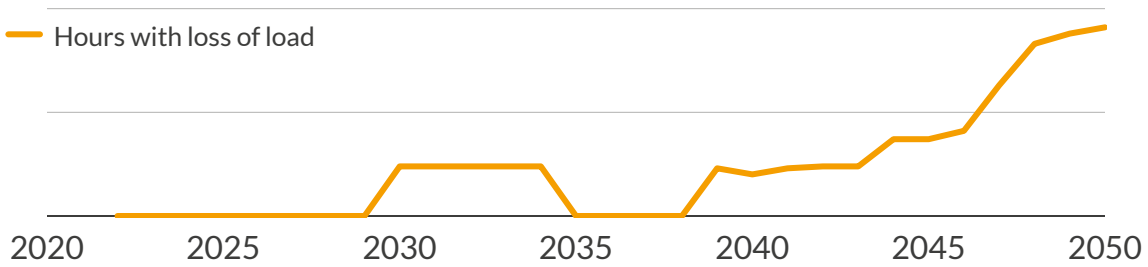
1 Projected prices are insufficient to encourage building sufficient firm capacity…

Illustrative present value for new build CCGT building in 2025/26 in GBR
£/kW



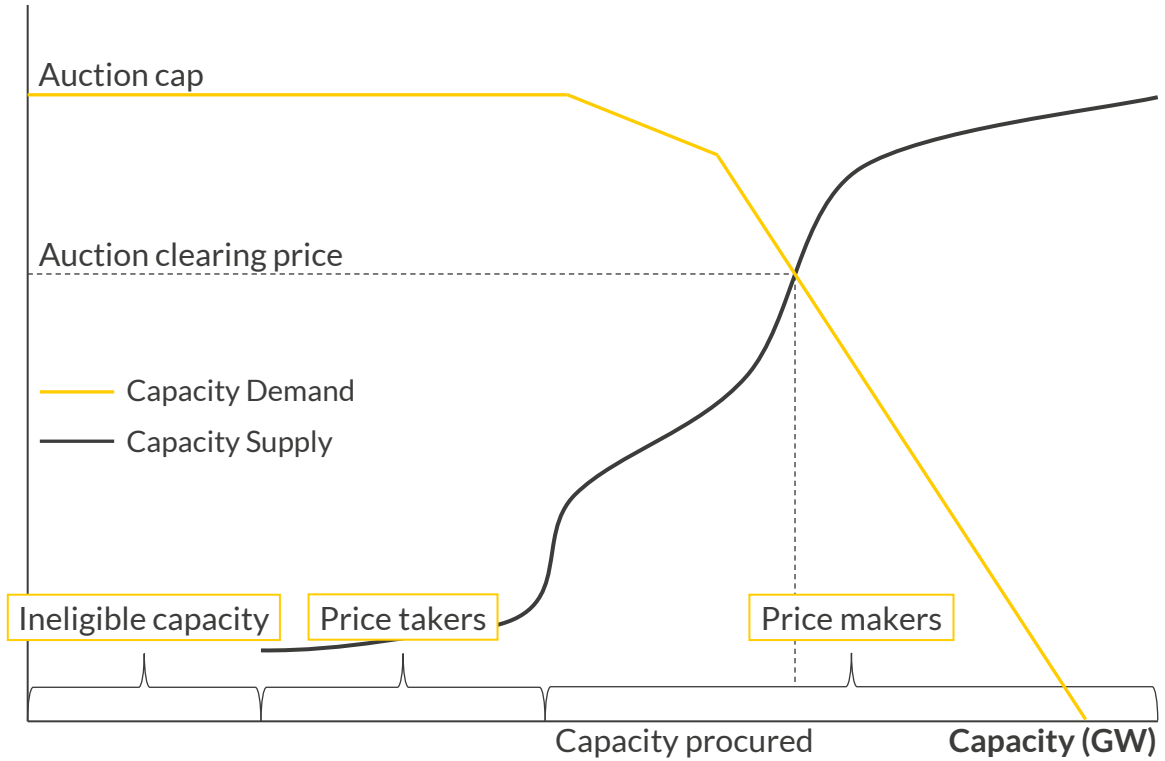
2 …which results in increasing shortfalls in generation over time

Illustrative hours with loss of load due to lack of firm capacity
h/year



3 A capacity market mechanism provides an additional revenue stream to encourage firm capacity to be built

Supply and demand prices in the Capacity Market
£/kW



Source: Aurora Energy Research

Capacity markets support over 27 GW of batteries across Europe, although revenues vary due to de-rating factors and clearing prices

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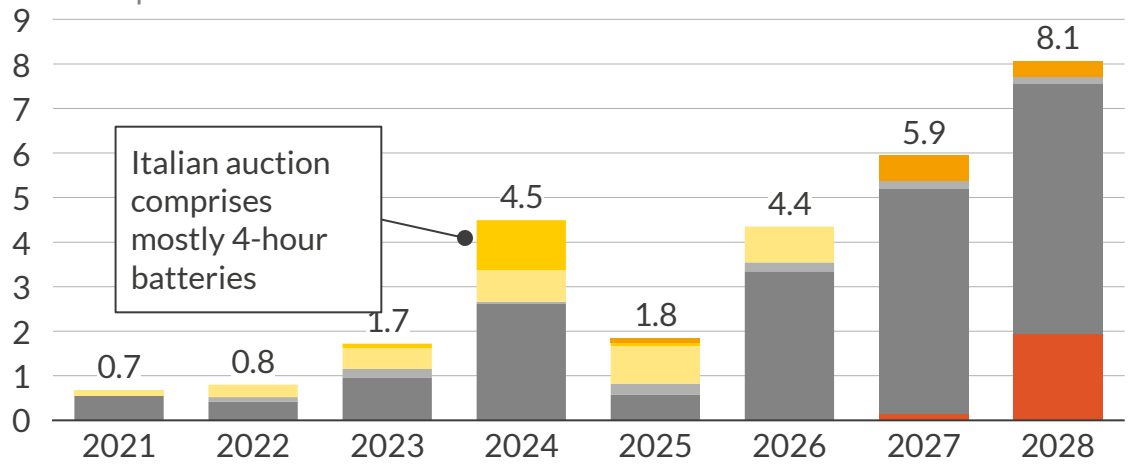
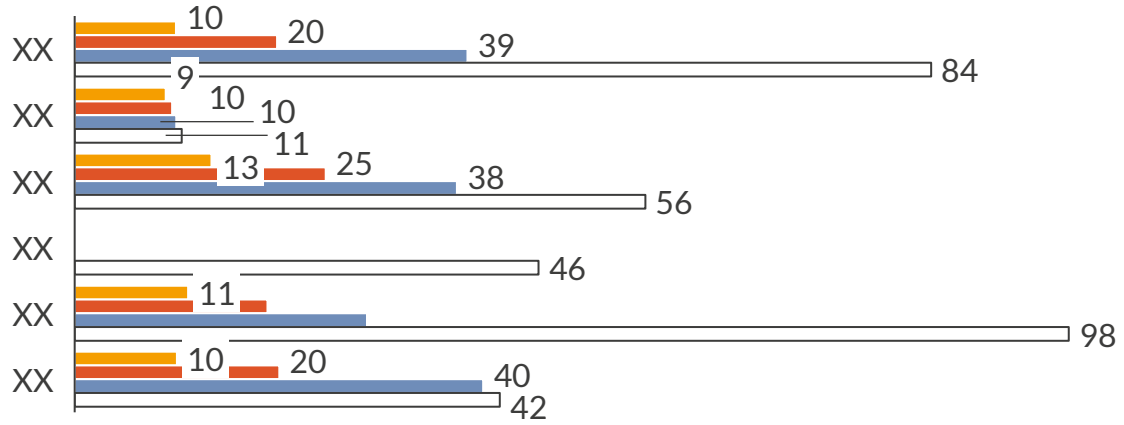
Total battery capacity with capacity market contracts by delivery year

GW nameplate



Cleared and de-rated capacity market prices by battery duration in latest auction

€/kW (real 2023)



- Over 27GW of batteries have secured contracts in capacity markets (CM) in six countries, of which 19 GW are located in Great Britain.
- In Great Britain, batteries dominated the 2027/28 T-4 auction, with 5.6 GW of batteries securing CM contracts, of which 4 hr batteries comprise 400 MW of nameplate capacity.
- Auctions are generally held at least annually, with delivery for new build assets typically 4 years after the conclusion of the auction.
- In Poland, the auction for delivery in 2028 awarded over 1.9 GW capacity to new battery assets.

- De-rating factors decrease the remuneration accessible to batteries in alignment with their role in ensuring security of supply, thereby restricting their earnings.
- Poland's capacity market requires 4 hours of continuous generation, so batteries with duration under 4 hours must compete with reduced capacity (half capacity for 2-hour batteries and quarter capacity for 1-hour batteries).
- Due to its pay-as-bid system, CM prices awarded to batteries in Belgium are not known
- Capacity market revenues generally only make a relatively small contribution to battery business cases, but can be important for securing finance

1) Average bid price for new capacity for the t-4 2023 auction. The highest awarded price bid in the 2023 Y-4 CRM auction was 69900 € /MW.

Source: Aurora Energy Research

BESS revenues in capacity markets are set to shift in the long term as clearing prices and de-rating factors continue to evolve (1/2)

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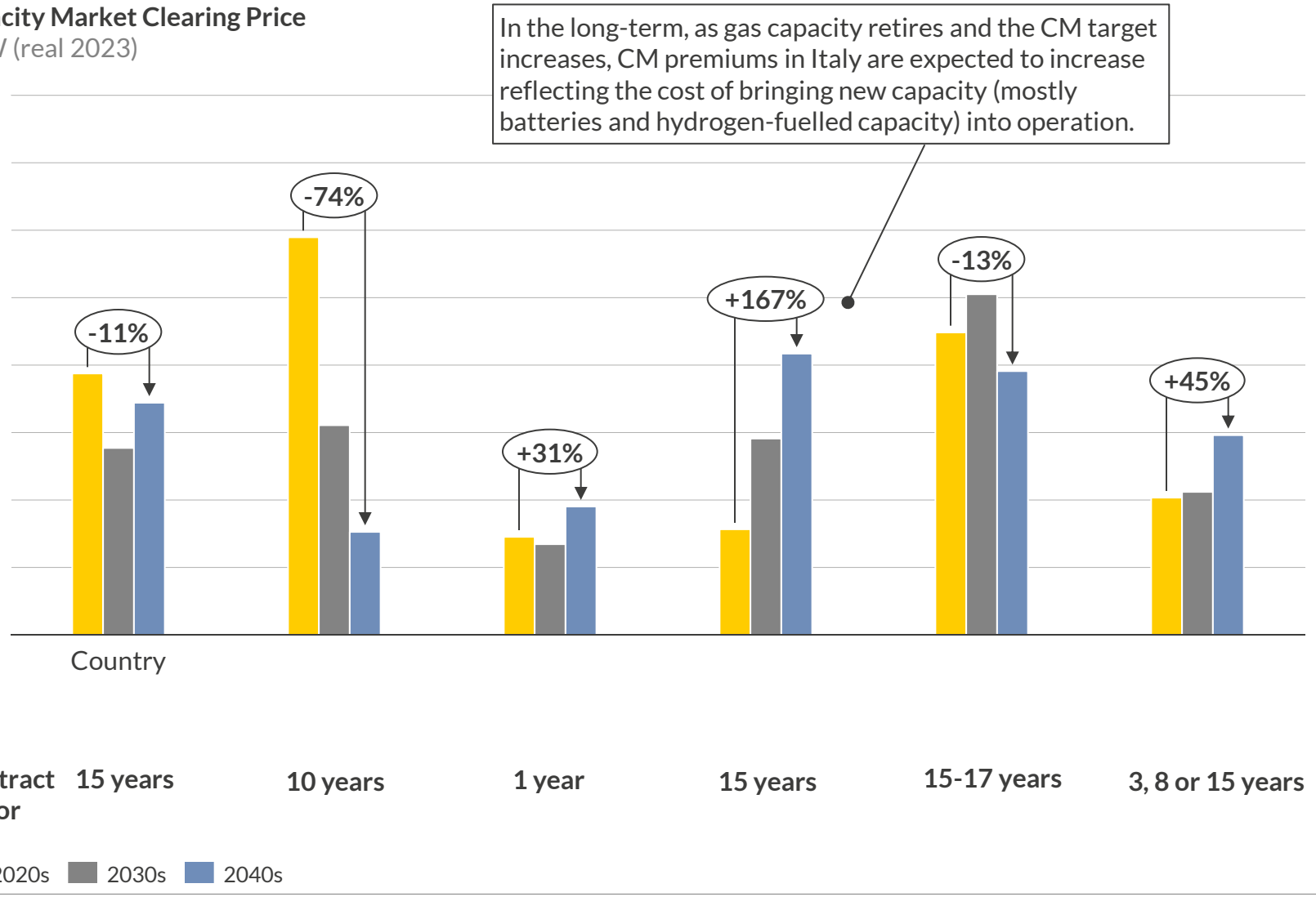
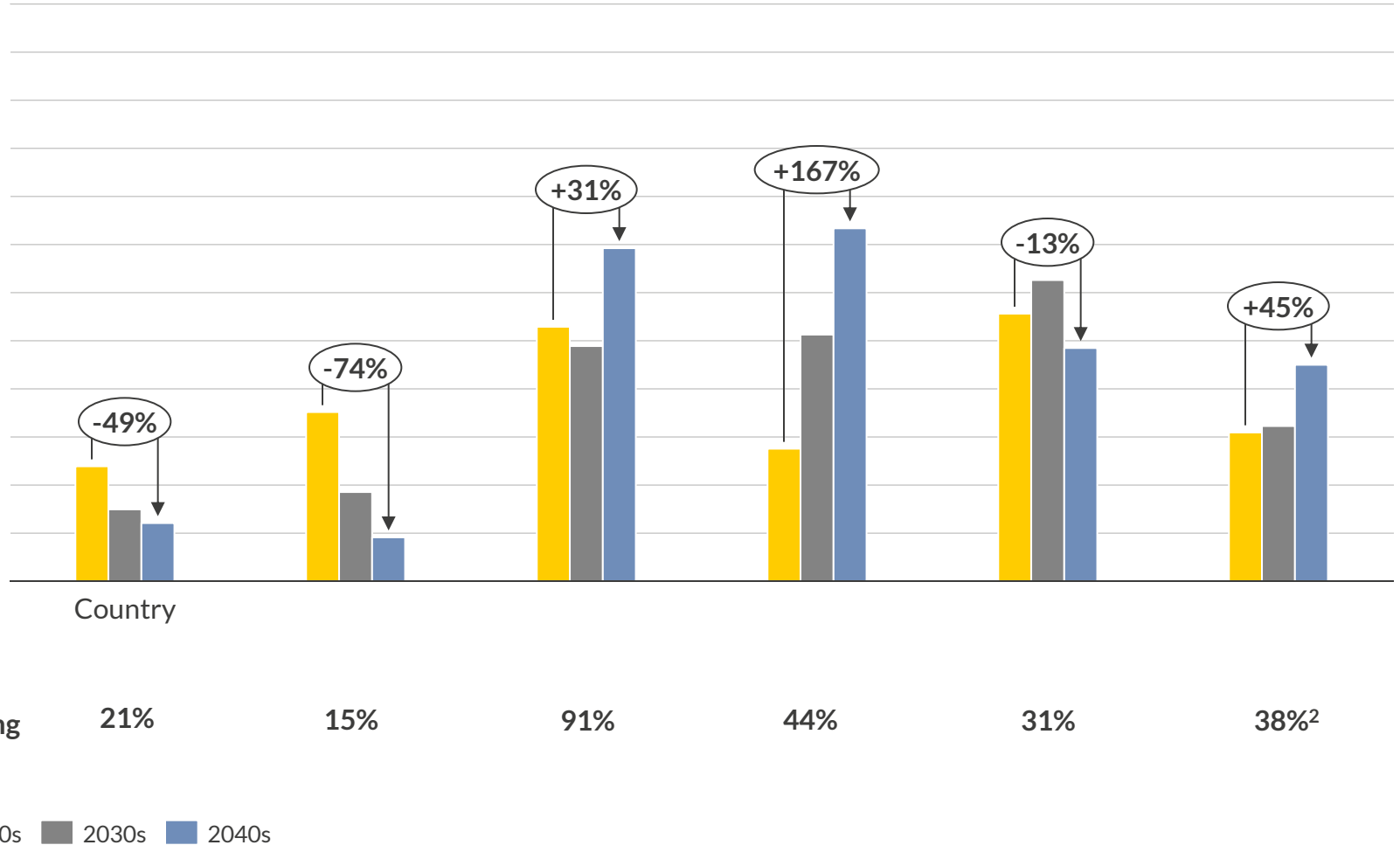
Capacity Market Clearing Price
€/kW (real 2023)



Source: Aurora Energy Research

BESS revenues in capacity markets are set to shift in the long term as clearing prices and de-rating factors continue to evolve (2/2)

Capacity Market revenue for 2-hour Battery Storage
€/kW, de-rated (real 2023)



Source: Aurora Energy Research

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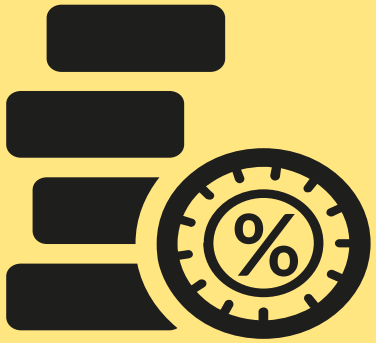
Executive Summary

Project economics



- Based on Aurora Central project IRRs with 2028 COD [redacted] sees the most attractive project economics for grid-scale battery storage, followed by Hungary and Belgium.
- 1-hour batteries are only expected to achieve unlevered IRRs above 10 [redacted]. In some countries, [redacted] hour business cases are not investable anymore due to [redacted].
- Besides [redacted], 2-hour batteries generate higher IRRs than 1hr batteries. Higher energy arbitrage revenues gain greater significance as duration increases, although CAPEX also rises with extended durations [redacted] highest 2-hour battery IRRs.
- In most of Europe [redacted] batteries generate the optimal business cases due [redacted]. However, in some markets the greater investment required to develop these assets does not pay off.
- Stacking of revenues is fundamental to building battery business cases and driving asset profitability.
- The gross margin stack is formed [redacted]
- The need [redacted] -hour batteries benefit most from [redacted]
- Gross margins in absolute terms tend to decrease over time due to market saturation and asset degradation.
- Developers can apply different strategies to improve their investment cases, such as repowering, co-location of assets, AI supported Intraday trading and grid location.
- [redacted]
- [redacted]

Source: Aurora Energy Research

Greece sees the most attractive project economics for battery storage, followed by Hungary and Belgium

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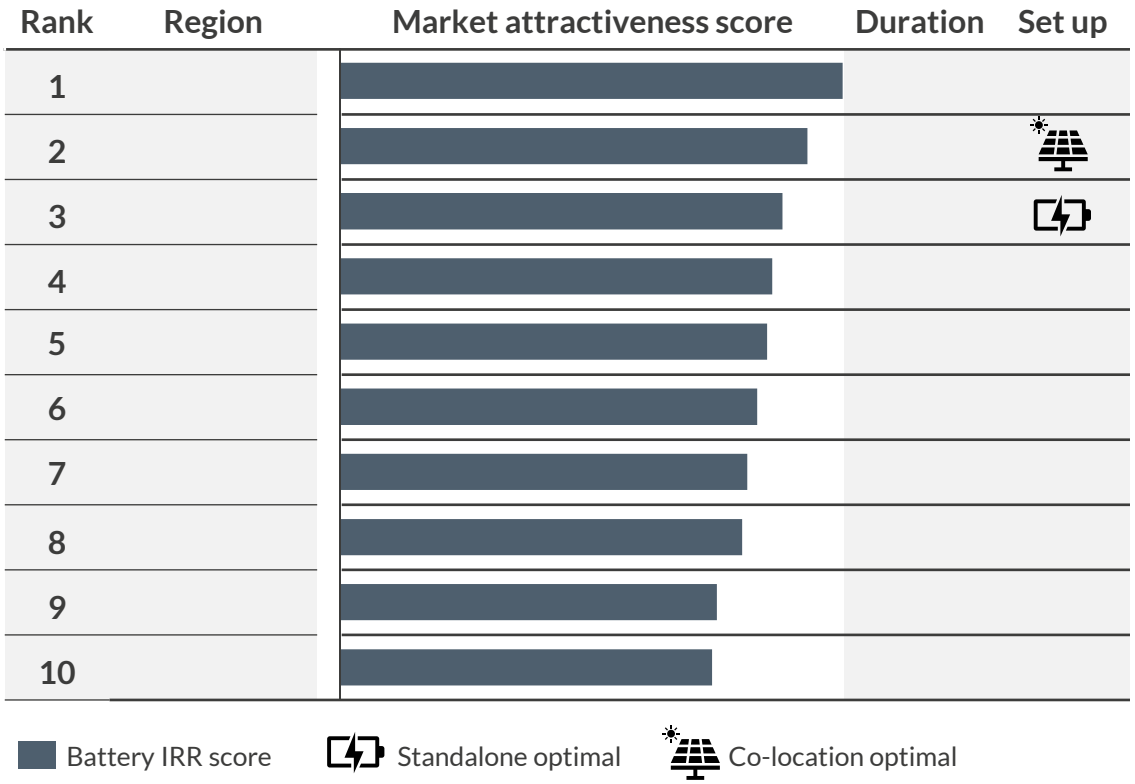
Project economics

Countries are assessed in terms of their economic outlook for batteries, reflected through indicative fully merchant IRRs in Aurora's Central cases, with scores assigned between 0-10. Scores do not equal IRRs.

Metric	Weighting	Rationale
12 Indicative fully merchant IRR for projects starting in 2027/28	100%	Captures the commercial viability of new build projects for final investment decisions in 3 years' time based on fully merchant business models



Top markets

- [redacted] has very attractive IRRs for 2hr batteries, driven by a combination of energy arbitrage and ancillary service revenues. Co-located solar PV and battery assets can reach moderate double-digit IRRs with a 2028 entry.
- [redacted] also shows IRRs above 12% for co-located PV and 2hr BESS projects entering the market in 2028 due to CAPEX/OPEX savings and lower exposure to charging fees than standalone batteries. Intraday price spreads are also expected to increase significantly in the short-term.
- [redacted] has the most attractive IRRs in Europe for 1hr batteries, as well as very strong economics for standalone 2hr batteries, driven primarily by energy trading. The growing market is supported by regulation, including partial grid fee exemption and a Capacity Market, that aims to accelerate the ramp-up of batteries and enhance the value of flexibility.

Source: Aurora Energy Research

Project economics are defined by regional differences such as revenue streams and regulation, but also can vary widely within a region

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1

1 Revenue streams

2 Regulatory factors

3 Battery utilization

4 Price zones

5 Commercial Operation Date

6 Co-location

7 Subsidy schemes

8 Repowering

9 AI trading

10 Market development

Project economics depends on region

Project economics depend on setup in the region

Source: Aurora Energy Research

BESS assets face certain challenges with project financing due to inconsistent cashflow… (1/2)

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1) Illustrative.

Source: Aurora Energy Research

…tolling agreements and innovative revenue models can be explored to improve bankability (2/2)

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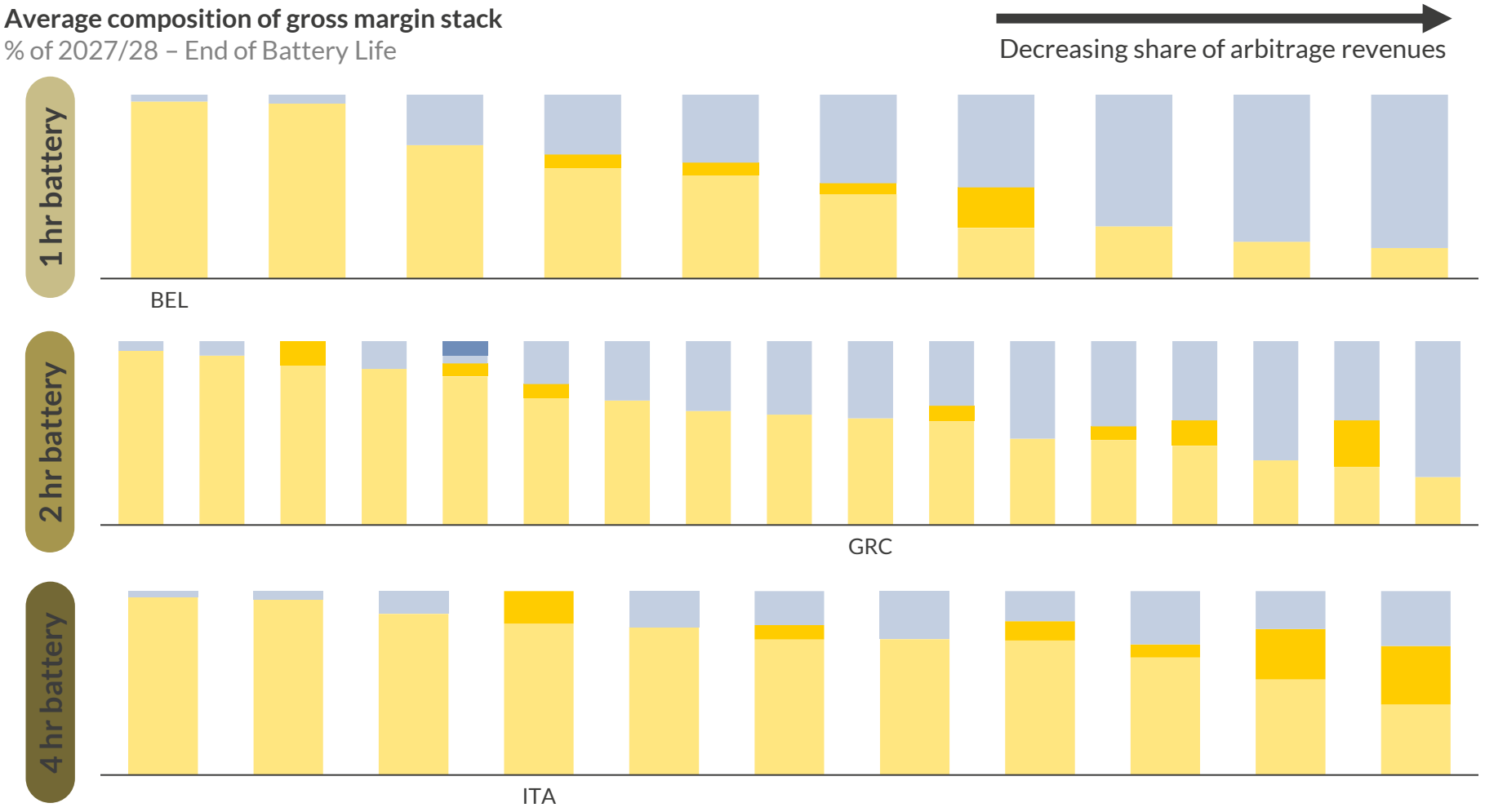
1

1) Illustrative. 2) A potential risk with revenue sharing arrangements is being stuck with an underperformer as received revenue greatly depends on operators' skill and ability.

Source: Aurora Energy Research

The largest share of revenue is formed by capacity-based ancillary services in the Nordics, but energy arbitrage is prevalent elsewhere

Average composition of gross margin stack
% of 2027/28 – End of Battery Life



Source: Aurora Energy Research

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1

- Energy arbitrage and capacity-based ancillary services are typically the main sources of revenues for batteries across Europe.
- Energy arbitrage is particularly attractive in [redacted] which have high penetration of variable renewables while capacity-based ancillary services are most attractive in the Nordics.
- Arbitrage revenue shares are typically highest in 4-hr batteries due to the longer timeframe available for charging and discharging, providing increased ability to take advantage of arbitrage opportunities.
- Contracted revenues, i.e. capacity market payments, increase with battery duration, [redacted], as longer duration assets offer greater support to security of supply.

Gross margins decrease over time as batteries degrade and markets saturate in most regions, but the level of impact varies

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2

- The increased build out of battery capacity saturates markets and leads to increased competition, dampening battery gross margins.
- With time and use, the storage capacity and depth of discharge of batteries decreases which is generally known as battery degradation and further holds back project value.
- In many countries, capacity-based ancillary services account for a high share of the battery gross margins in the early years. However, energy arbitrage becomes increasingly important in the long term, e.g. in Denmark and Spain.
- Contracted revenues, i.e. capacity market payments, typically account for higher margin shares in later years as market design is enhanced for energy security, e.g. in Spain and Poland.

1) Representative of a BESS asset with a 2028 entry year; 2) Represents DK2; 3) Representative of solar PV and BESS co-location cases.

Source: Aurora Energy Research

In [redacted] and [redacted] degradation is counterbalanced with better access to revenue streams, gross margins increase from 2028 levels

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2

1) DS3 is the suite of ancillary services in Ireland introduced in 2018 to reinforce the power system and accommodate greater renewables penetration; 2) Represents the South England & Wales region; 3) Includes Triads and GDUoS benefits in GBR.

Source: Aurora Energy Research

With increased ancillary market saturation, energy arbitrage revenues drive 2- and 4-hour business cases throughout most of Europe

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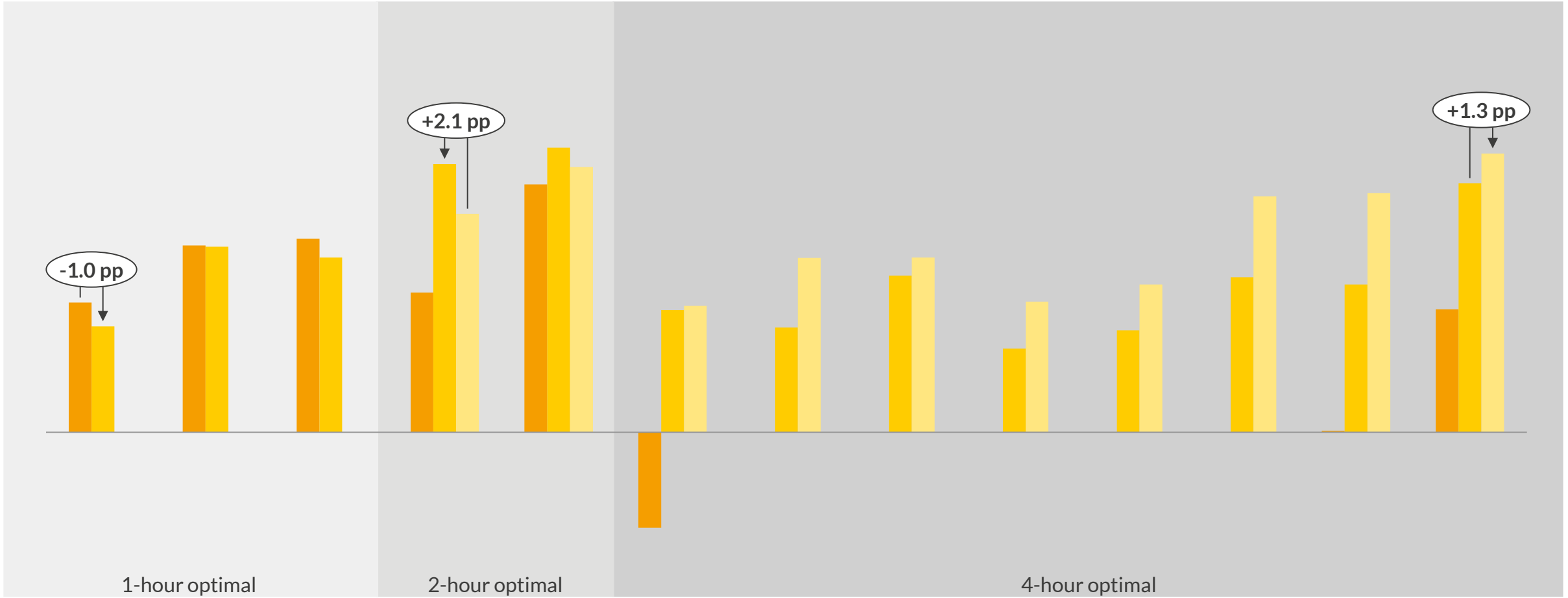
Project IRR ranges for standard projects (2027/28 entry year)[1] – Europe
%, Central scenarios, categorised by optimal battery duration



1) Standard case represents standalone business cases without repowering for assets optimising among energy arbitrage, capacity-based ancillary services, and capacity markets cashflow. IRRs are based on Aurora's internal cost assumptions. 2) The introduction of a Nordic mFRR capacity market could boost ancillary market revenues by a further 10%, though this has not been included in the forecast; 3) Represents SE4; 4) Represents DK2; 5) Represents average IRR across Italian price zones.
Source: Aurora Energy Research

Locational factors are strong drivers of potential returns in markets like Great Britain

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In GB, asset location greatly impacts earnings

1) Standard case represents standalone business cases for assets optimising among energy arbitrage, capacity-based ancillary services, and capacity markets cashflow. IRRs are based on Aurora's internal cost assumptions. 2) Aurora's modelling methodology assigns all GB assets to a dispatch zone; 3) GB central scenarios consider repowering of 2h batteries with 1.5 cycles.
Source: Aurora Energy Research

Batteries with later commissioning dates can expect lower returns, except in Iberian co-location business cases

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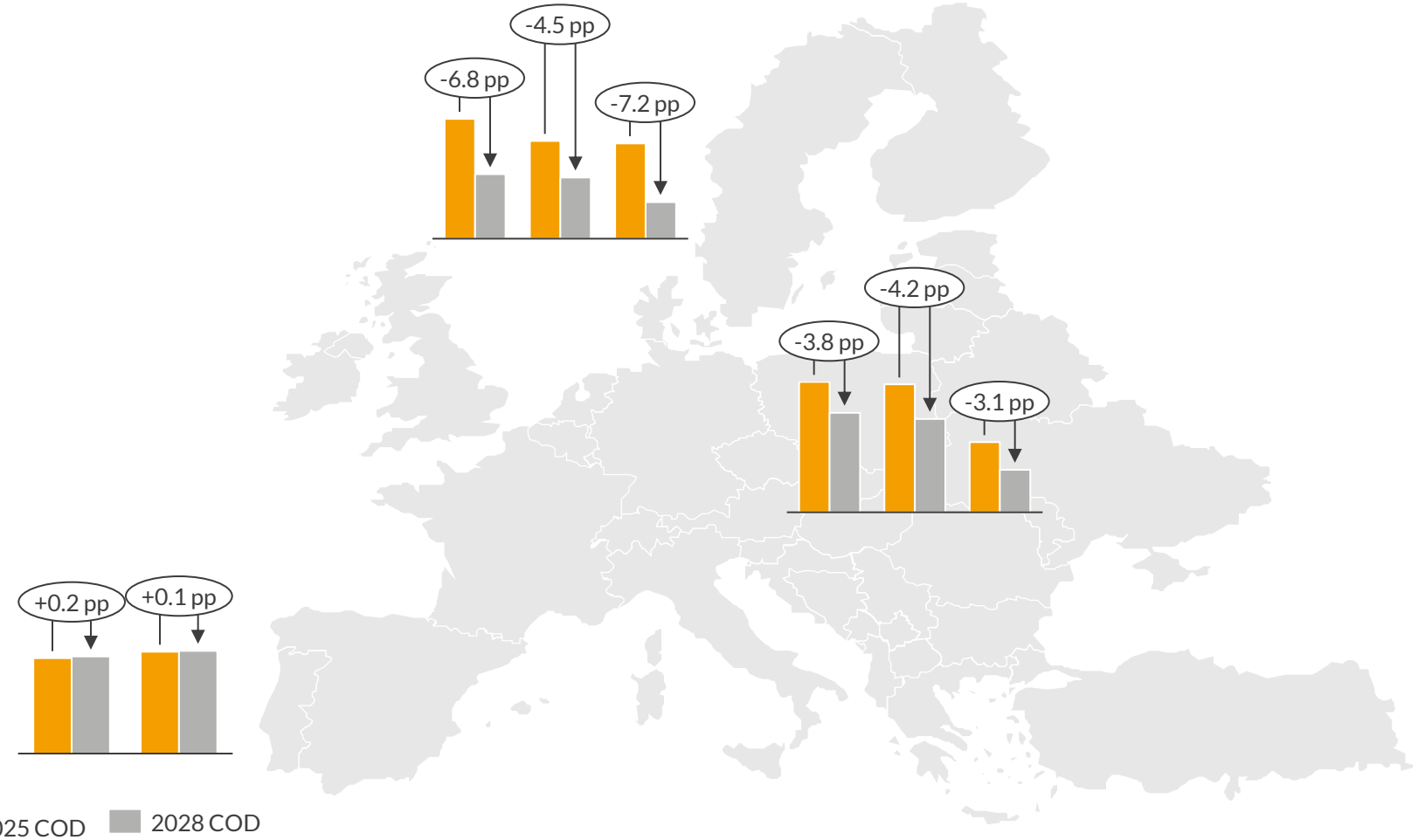
Profitability of batteries strongly depends on the entry year

Project IRRs for varying 2-hour business cases – Europe

%, pre-tax real, unlevered, Central scenarios



Source: Aurora Energy Research

Co-location of batteries with renewables can increase battery IRRs through cost savings and project optimisation

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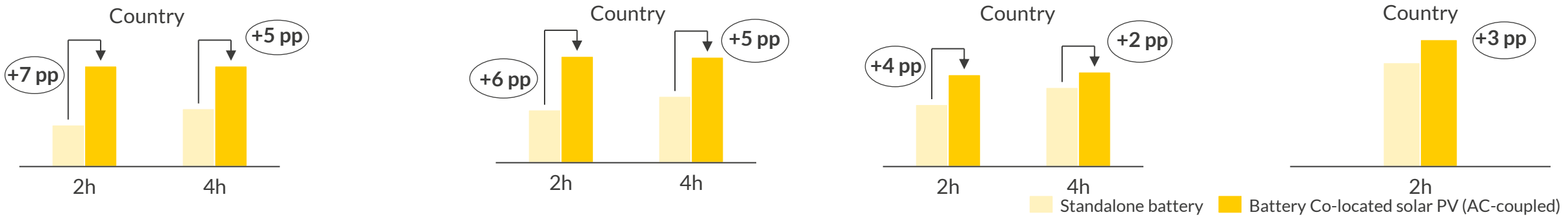
6

Project IRRs: Standalone vs Co-location cases



Factor	Description	Benefit
CAPEX savings	CAPEX cost savings due to simplified installation with respect to two separate projects	Partial cost savings on development costs, BoS costs, EPC costs and grid connection costs
OPEX savings	OPEX cost savings due to simplified operations	O&M costs can be reduced due to synergies between the solar and the battery assets
Portfolio benefits	Protection from technology related downside cases	Full portfolio benefits
Solar curtailment optimisation	Inverters at solar assets are usually undersized, leading to a small portion of the output to be spilled	Battery can capture part of the spilled solar output. However, in cases in which the solar asset is oversized, clipping losses might decrease the amount of energy that the battery can absorb
Inverter losses	Conversion steps from DC to AC lead to electricity losses	Similar losses to stand-alone battery, since power goes through two inverters
Battery dispatch	Battery asset may need to operate around renewables generation	Storage output might be restricted by solar generation
Sub-optimal siting and sizing	Relative impact on business model compared to standalone case	By being limited to locations and grid size of a solar asset, the battery is limited in how it can be optimised

Source: Aurora Energy Research

Subsidy schemes and repowering are additional measures that should be considered to optimise project economics

7

IRR comparison: MACSE & merchant tail vs Fully merchant with Capacity Market

8

IRR comparison: Repowering vs Standard lifetime

1) Standalone cases for 4h batteries entering in 2028, averaged across Italian price zones; 2) Aurora assumes repowering at 63% state-of-health.

Source: Aurora Energy Research

Advanced trading strategies on the Intraday market could represent a major upside for batteries

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1) Continuous Intraday Trading 2) PV calculated based on discount rate of 11.5% WACC (real); 3) Represents a standalone, 2h duration battery entering in 2028.

Source: Aurora Energy Research

Aurora's Low scenario illustrates how market uncertainties can adversely impact battery investment returns (1/2)

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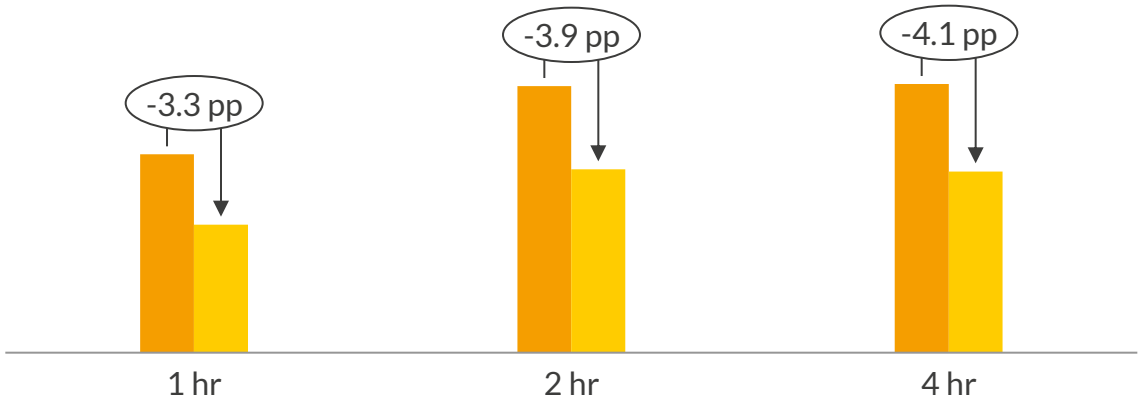
Natural gas prices Low vs Central
€/MWh (real 2023)

IRR comparison: Aurora Low vs Central scenarios



Annual power demand Low vs Central
TWh

Central Low

Source: Aurora Energy Research

Aurora's Overbuild scenario illustrates how market uncertainties can adversely impact battery investment returns (2/2)

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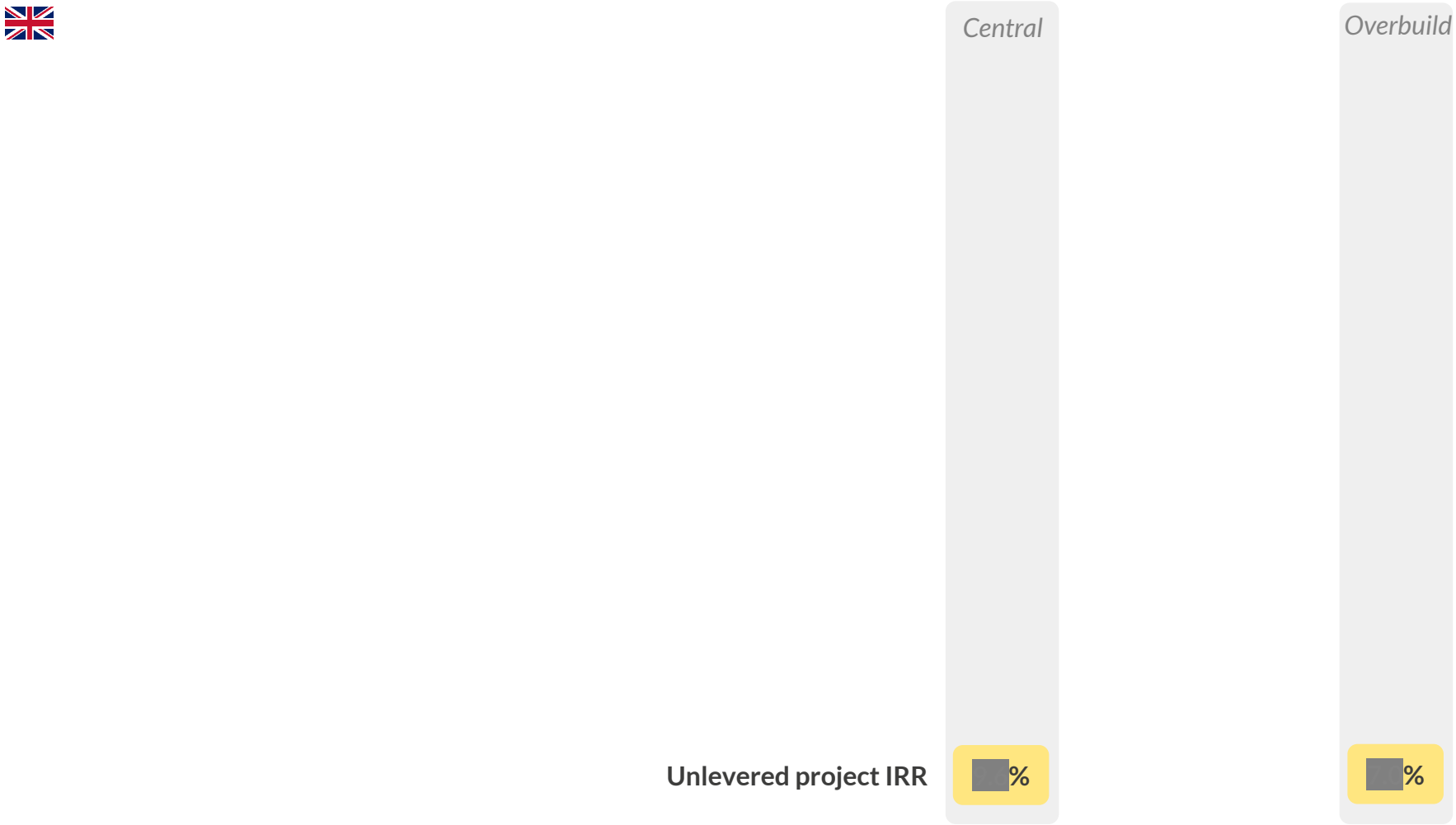
IRR comparison: Aurora Overbuild vs Central scenarios



Agenda

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Step 1: Unique, proprietary, in-house modelling of power markets

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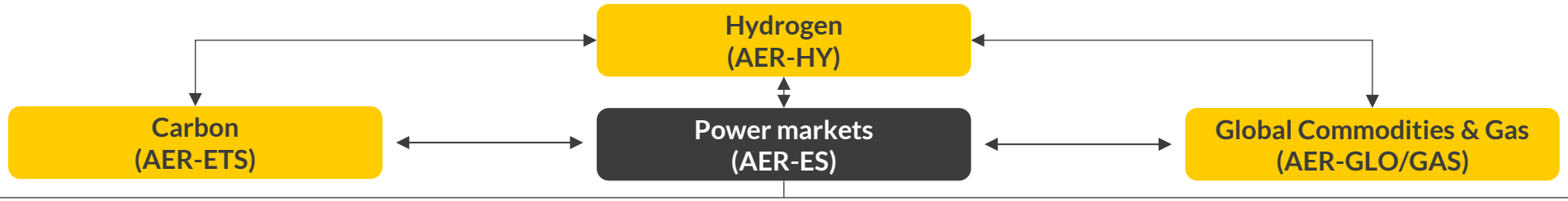
4 Integrated Models



INPUTS

- Technology
- Policy
- Demand
- Commodity prices[1]
- Weather patterns

Dispatch model

- ½ hourly or hourly
- Iterative modelling
- Dynamic dispatch of plant
- Endogenous interconnector flows

Continuous iteration until an equilibrium is reached

Investment decisions module

- Capacity market modelling
- Capacity build / exit / mothballing
- IRR / NPV driven
- Detailed technology assessments

OUTPUTS

- Capacity mix
- Generation mix
- Wholesale & imbalance prices
  Deepdive on next slide
- Capacity market prices
- Profit / Loss and NPV
- Electric vehicle charging

1) Gas, coal, oil and carbon prices fundamentally modelled in-house with fully integrated commodities and gas market model

Source: Aurora Energy Research

Step 2: Ancillary market modelling, example of FCR in Germany

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FCR model

Aurora's Power Market Model

- All calculations for the FCR are underpinned by Aurora's fundamental, in-house power market model, which outlines the overall, long-term system developments, wholesale market prices and capacity developments.

We import a variety of outcomes into our FCR market model, most importantly:

- Wholesale prices
- Capacity market forecasts
- Capacity and generation mix
- Granular asset performance

Aurora's FCR Market Model

a Determining asset-level FCR bids

- Bids are based on the cost of maintaining a dispatch level that allows for (symmetric) FCR bids and opportunity costs compared to developments in the Day-Ahead market.
- All bids must be symmetric and for 4h blocks, in line with current market design.

Bids of all participating assets in all countries

b Merit order clearing across borders

- After assembling all the bids, the FCR model calculates national elements such as export limits and core shares.
- Finally, the merit orders get cleared and successful assets are remunerated pay-as-clear.

Source: Aurora Energy Research

Further comments

- Aurora's FCR market model accounts for all core design elements of the market:
  - Countries' core shares
  - Countries' export limits
  - Ramping rates
- If no constraint is hit, the local marginal price in each country is equal to the cross-border marginal price (this is the most expensive awarded bid in cooperation).
- If the core limit or export limit is hit, the local marginal price is based on the local awarded bid within each country.

Step 3: Aurora models battery business cases based on our in-house battery dispatch software Chronos

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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

A Chronos[1] battery trader

Day 1
Scheduling Phase → Dispatch Phase

Day 2
Scheduling Phase → Dispatch Phase

…

Day n
Scheduling Phase → Dispatch Phase

Results

- Battery dispatch
- Revenues per market
- NPV and IRR

X Deep dive on next slide

1) Includes intermarket optimization such as **buying back** commitments on the ID to fulfill a DA commitment if the price is more attractive, **adding cycles** by selling earlier than committed on the DA market if an ID spread is observed, and **optimising** between the aFRR energy & ID markets depending on the more attractive price, does not include intra-market optimisation through asset backed trading such as continuous trading of 15-minute products on the ID and trading the same quarter hour multiple times.

Source: Aurora Energy Research

Our dispatch model optimises daily between energy arbitrage and ancillary services

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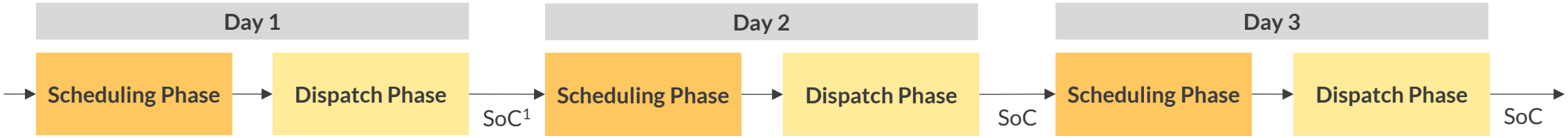
Our battery dispatch model is solved in **blocks of 1 day** (96 quarter-hours), determining all actions for each block before moving onto the next block. Each block is solved in two stages:



Scheduling Phase

Outputs:

- Day-Ahead wholesale market positions (at hourly granularity)
- FCR and aFRR capacity markets (at 4-hourly block granularity) commitments

Method:

The Scheduling Phase is solved with an optimisation approach, with up to 32h foresight of remaining prices (for Day-Ahead, FCR, and aFRR capacity). Participation in these markets also accounts for the opportunity cost of participating in the Intraday and the aFRR energy markets.

Dispatch Phase

Outputs:

- Fulfilment (or non-fulfilment) of Day-Ahead, FCR, and aFRR capacity commitments
- Intraday market charging/discharging
- aFRR energy markets charging/discharging

Method:

Day-Ahead, FCR, and aFRR capacity commitments are fulfilled first (subject to SoC conditions). The commitments of the Intraday and the aFRR energy markets are determined using a heuristic price threshold approach based on upcoming Day-Ahead prices. No foresight for the Intraday and the aFRR energy markets is assumed. Model accounts for upcoming commitments and applies penalties for missed actions.

1) State of charge.

Source: Aurora Energy Research

Details and disclaimer

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