AURORA ENERGY RESEARCH

REDACTED

European Battery Markets Attractiveness Report

February 2024

3RD EDITION

Aurora European Battery Markets Attractiveness Report:
Inform your next business move in Europe with this comprehensive report

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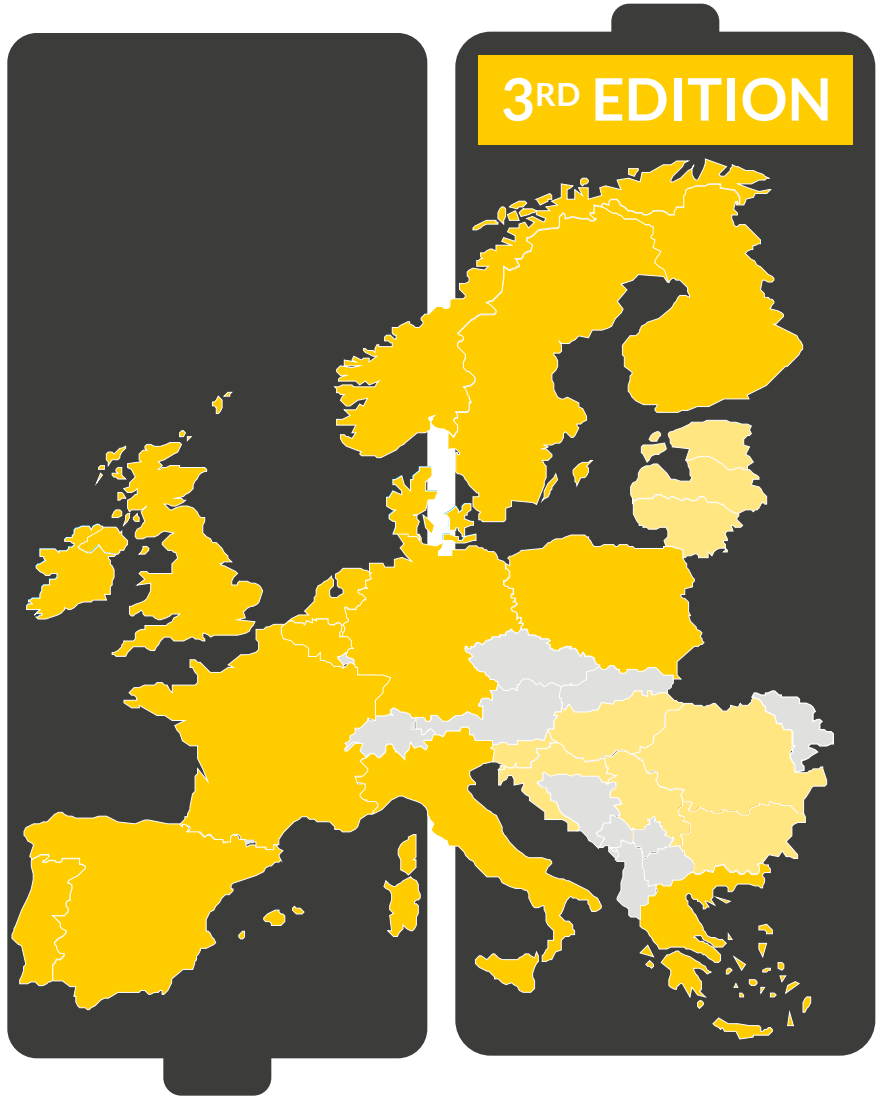
Analysis across 24 European countries:

- Great Britain*
- Ireland (I-SEM)*
- France*
- Belgium*
- The Netherlands*
- Germany*
- The Nordics* (Denmark, Finland, Norway, Sweden)
- Iberia* (Portugal, Spain)
- Italy*
- Poland*
- Greece*
- Hungary
- Romania
- Serbia
- Bulgaria
- Slovenia
- Croatia
- The Baltics (Estonia, Lithuania, Latvia)



With over 100 analysts and modellers working across our European Flexibility Energy Market Services, this report provides you with a summary of our credible, reliable, and bankable forecasts

Access this report for:

- **European Battery Market Trends – Market Size and Opportunity**
  - Installed capacity, battery investment trends, and near-term pipeline
  - Forecast volumes for battery deployment by year and country
- **Policy and Regulatory Environment analysis**
  - European and national battery strategies, targets and plans
  - Analysis of anticipated regulatory changes impacting battery markets
  - Assessment of policy risks including aggregation of demand side assets, and grid connection
- **Battery Storage Business Models and Value Drivers**
  - Summary of attainable markets and revenue stacking opportunities
  - Comparison of value drivers across markets including RES penetration and daily wholesale market spreads, balancing services and capacity market auctions
  - Assessment of saturation risk for each country
- **Battery Economics and Business Cases. See above plus:**
  - Revenue stacking opportunities and normalised gross margins (1, 2 and 4 hours)
  - Investment cases (estimated IRR ranges) for hybrid business models (optimised between energy arbitrage and ancillary services)

New features:

- A 90-minute call with our European expert analysts with every report purchase
- Overview of historical and upcoming BESS auctions
- Market specific updates to policy and regulation impacting BESS
- Strategies to maximise upside in BESS business cases including examples

For markets (*) Flexible Energy Market Services with detailed forecasts & business case analysis are available

Source: Aurora Energy Research

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 valuable revenue streams for batteries in the covered countries, details of our ranking methodology, the market attractiveness scores and our rankings of the countries.
- **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 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 representative assets.
- **Section VII *[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 3rd 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 2nd publication, several changes have occurred in the BESS market in Europe, which we examine in this 3rd Edition.

What's new?

1 Refreshed analysis and policy updates

- Updated BESS cost projections reflecting recent lithium-ion trends
- Refreshed gross margin and IRR analysis based on Aurora's latest power market forecasts
- Analysis on policy competition from distributed energy resources (DER), electrolysers and electric vehicles (EVs)
- Analysis of additional investment opportunity from repowering
- Market specific updates to policy and regulation impacting BESS
- Overview of historical and upcoming BESS auctions
- Overview of key market players, including top developers, battery suppliers, integrators and route-to-market providers

2 Improved market attractiveness metrics

- New metric within the policy section, reflecting the policy competition risk for batteries from aggregation of DER, electrolysers and EVs
- Redesign of grid integration metric, covering ease of grid access and favourability of grid fees
- Redesign of co-location metric covering regulatory and market access attractiveness
- Redesign of project economics metric to reflect business cases for 1, 2, 4 hr batteries and co-location
- New market rankings

Source: Aurora Energy Research

Aurora is the leading commercial advisor for battery storage investments and transactions in Europe

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Deeply experienced in investment & business case analysis

- Aurora have advised >3GW of battery storage projects in Europe
- Our forecasts have enabled battery investments of >£1.5bn
- Over 250 developers, investors, utilities and banks subscribe to Aurora's regular revenue stream and battery business case forecasts in Europe

Extensively relied upon for debt financing

- Aurora forecasts have helped to raise >£600m of debt financing for battery storage projects
- We provided reliance to 10+ banks to debt finance battery projects

Widely trusted for regular fund valuations

- Aurora provides forecasts for regular valuation of 3 listed battery funds with total Net Asset Value of >£1.6bn
- Renewable & Energy Transition funds with >£100bn AUM use Aurora forecasts for their battery storage valuations & investments

Source: Aurora Energy Research

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 Pivot Power on sale of company and 2GW portfolio to EDF
- 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

1) Ancillary Services.

Source: Aurora Energy Research

Flexibility Market add-on service: Provides detailed power market analysis and investment cases for batteries in 14 European markets

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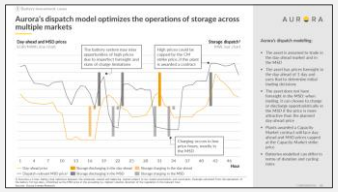
Flexibility Market add-on service

Forecast reports & data

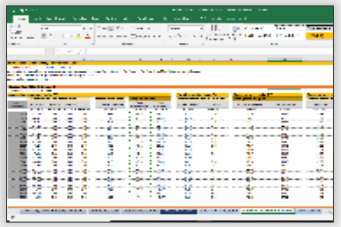
Technology and market development reports

- 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

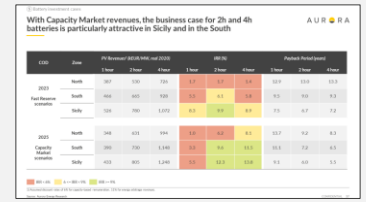
- Central case forecast prices provided at settlement period granularity until 2050
  - Wholesale power prices
  - Balancing market prices
  - Ancillary services prices



Investment cases

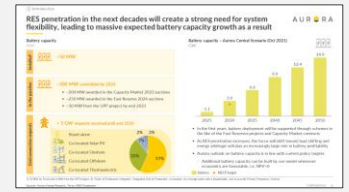
Standalone Battery

- 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

Agenda

Want to see the whole report?
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alex.hutcheson@auroraer.com

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.*

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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)

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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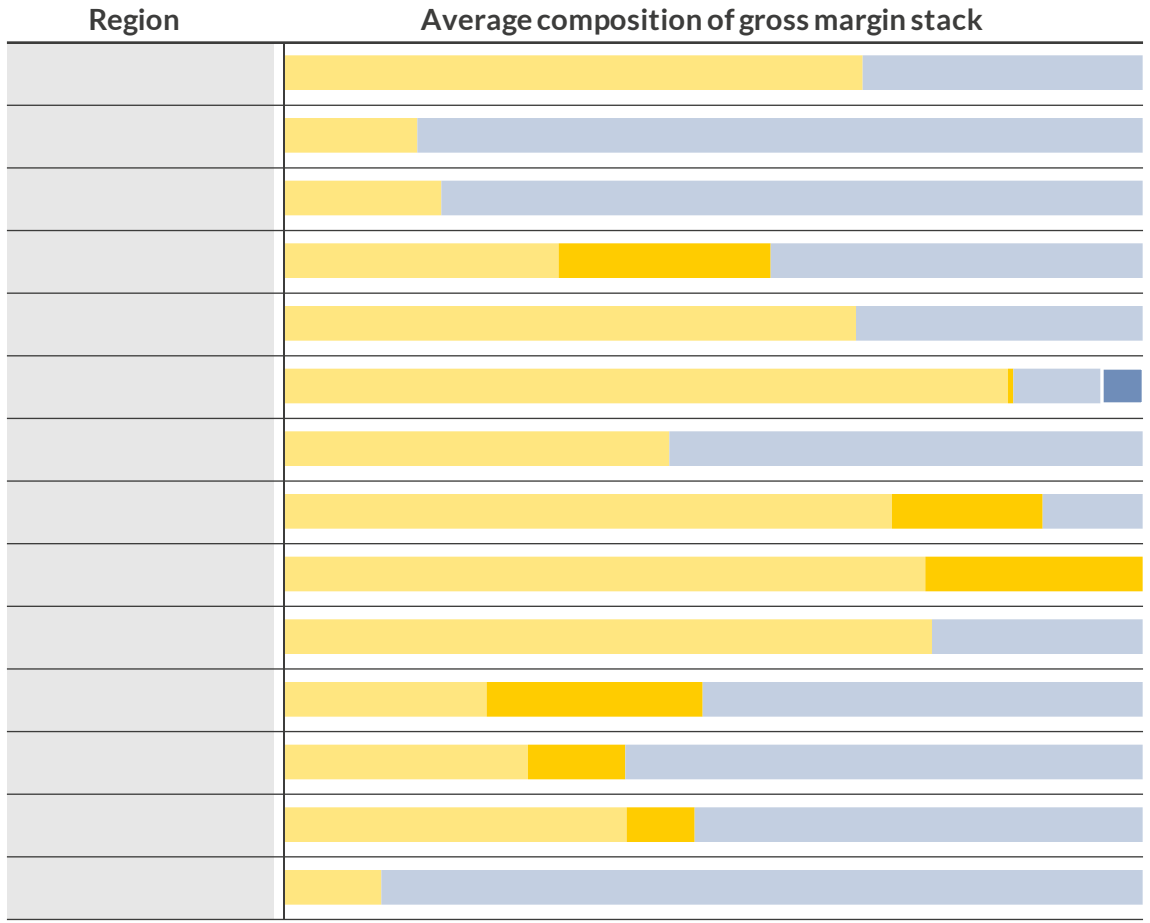
Summary of gross margin stack market composition

% of 2027 – 2041, 2h duration batteries



4) Includes fast frequency products with full activation time < 10 minutes such as FFR, FCR and aFRR; 5) Includes Balancing Mechanisms in Great Britain and Ireland and slower frequency products with full activation time > 10 minutes such as mFRR, RR, Secondary/Tertiary Reserves within Italy's MSD, and reactive balancing in Belgium and the Netherlands.

Source: Aurora Energy Research

Aurora's rating combines 13 metrics to derive an overall attractiveness score for 24 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 13 metrics, which are set out in detail in this report.

Categories and metrics	Weighting	Rationale	Source of data
Market size and outlook	**25%**		
1 Current installed battery capacity	*40%*	Demonstrates current market size and impact on energy security	Aurora fundamental modelling*
2 Battery capacity deployment to 2030	*50%*	Indicates expected future market size	Aurora fundamental modelling*
3 Battery investment required by 2030	*10%*	Indicates future investment need, reflecting storage duration and repowering	Aurora fundamental modelling*
Policy environment	**25%**		
4 National battery targets and policies by 2030	*20%*	Demonstrates policy ambition for battery storage deployment	Aurora analysis
5 Renewables targets by 2030	*20%*	Demonstrates policy ambition around renewables deployment	Aurora analysis
6 Availability and contractability of revenue streams	*30%*	Indicates availability and long term contractability of revenues	Aurora analysis
7 Grid Integration risk	*20%*	Indicates current regulatory risks around grid connection and fees	Aurora analysis
8 Competition risk	*10%*	Indicates regulatory risks around aggregation[1], electrolysers and EVs	Aurora analysis
Revenue Streams for battery storage	**25%**		
9 Average wholesale market daily spreads	*50%*	Indicates the value available from energy arbitrage	Aurora fundamental modelling*
10 Frequency and balancing markets saturation risk	*25%*	Demonstrates the risks of market saturation	Aurora analysis
11 Capacity market revenues	*25%*	Indicates the value available from receiving capacity market payments	Aurora analysis
Business models and cases	**25%**		
12 Indicative merchant IRR for projects starting in 2027 (incorporates IRRs for 1,2,4 hr and co-located assets)	*80%*	Captures the commercial viability of new build merchant projects for final investment decisions in the next few years	Aurora fundamental modelling*
13 Co-location potential	*20%*	Indicates the policy environment value from co-locating with renewables	Aurora analysis

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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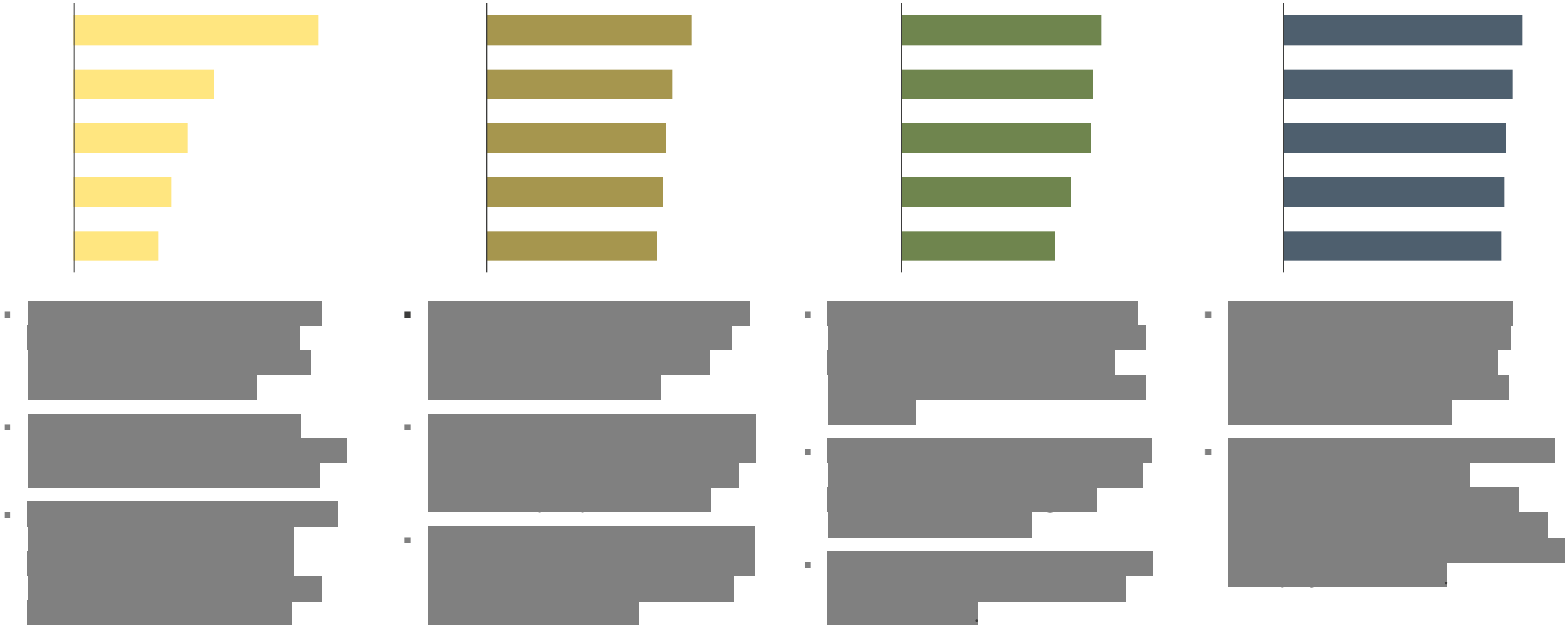
Market size and outlook

Policy environment

Revenue streams

Project economics



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Source: Aurora Energy Research

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

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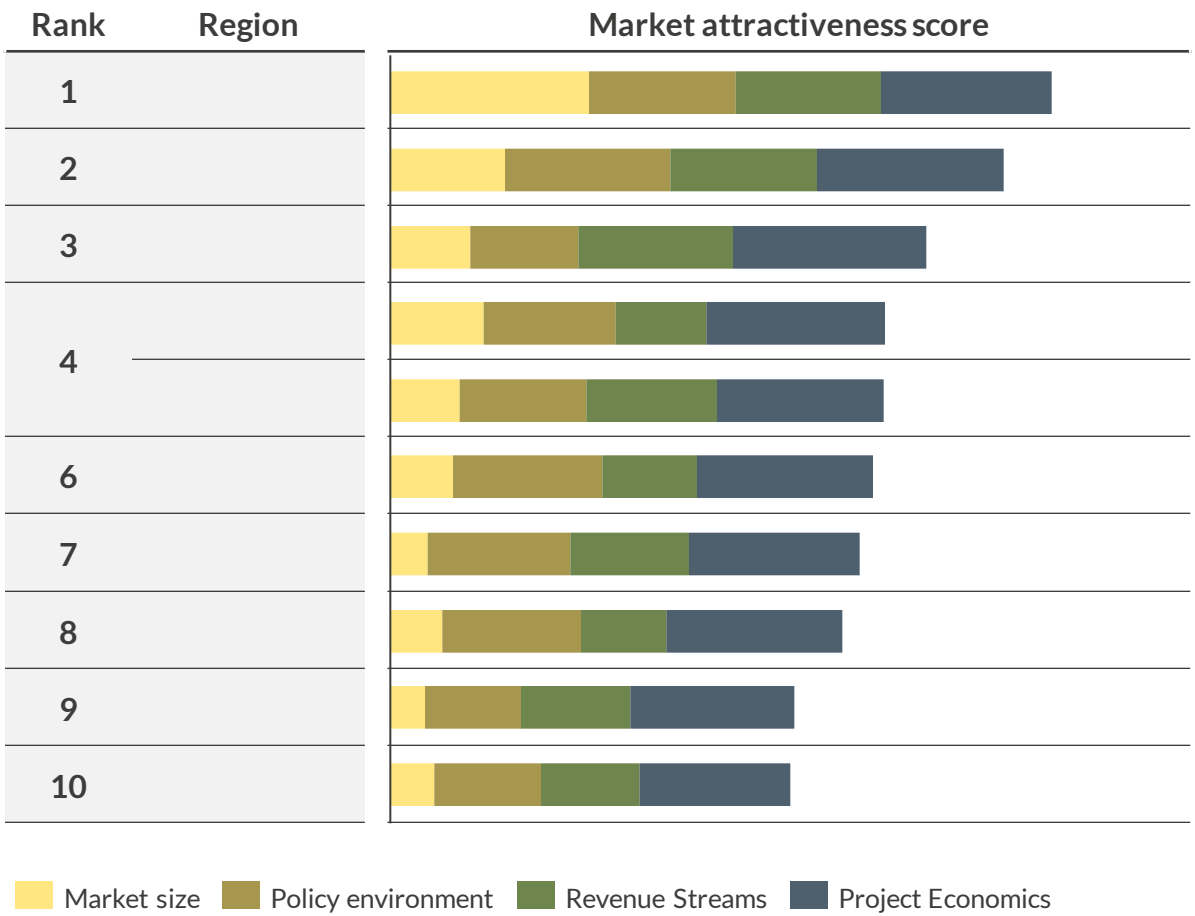
Installed capacity of battery storage across Europe currently stands at [redacted] GW, making up less than 1% of total installed capacity. It is projected to grow nearly [redacted] to [redacted] GW by 2030, requiring [redacted] bn € CAPEX investment.



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Source: Aurora Energy Research

[redacted] was the most attractive market; [redacted] has dropped down the rankings

Region	Current rank[1] (3rd edition)	Change in rank	Previous rank (2nd edition)	Key change drivers and recent highlights
	1			
	2	▲		
	3	▲		
	4	▲		
		▼		
	6	▲		
	7	▼		
	8			
	9	▲		
	10	▼		

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Source: Aurora Energy Research

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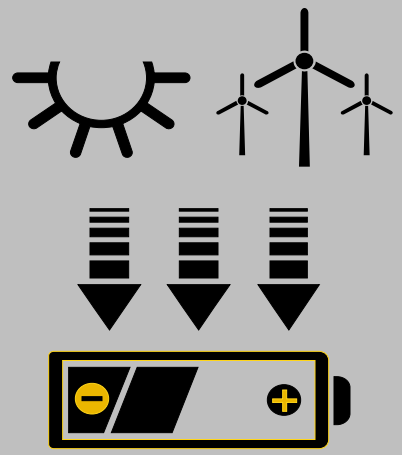
Executive Summary

Introduction to battery storage



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Source: Aurora Energy Research

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

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1) For more information on alternative technologies, see slide 30. 2) Energy capacity is the total amount of energy able to be stored by the asset, defined in megawatt-hours (MWh).

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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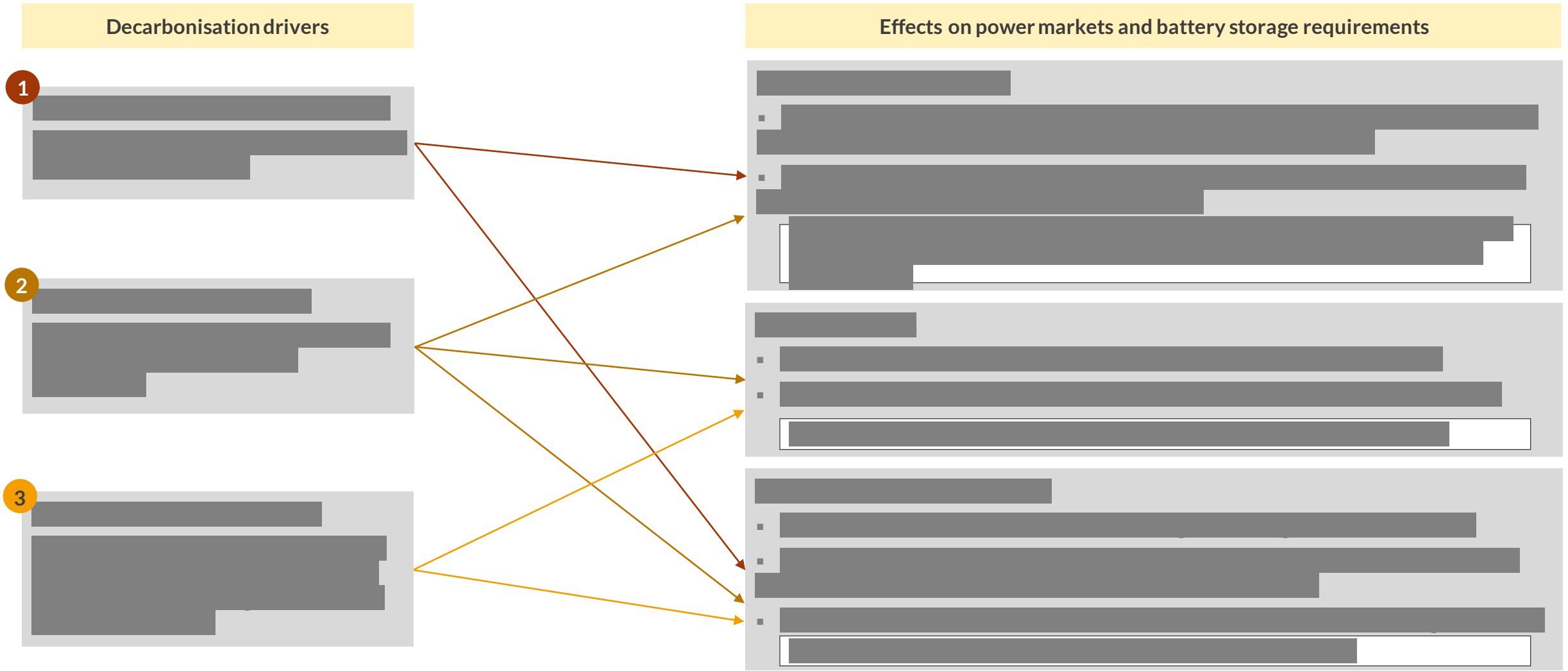
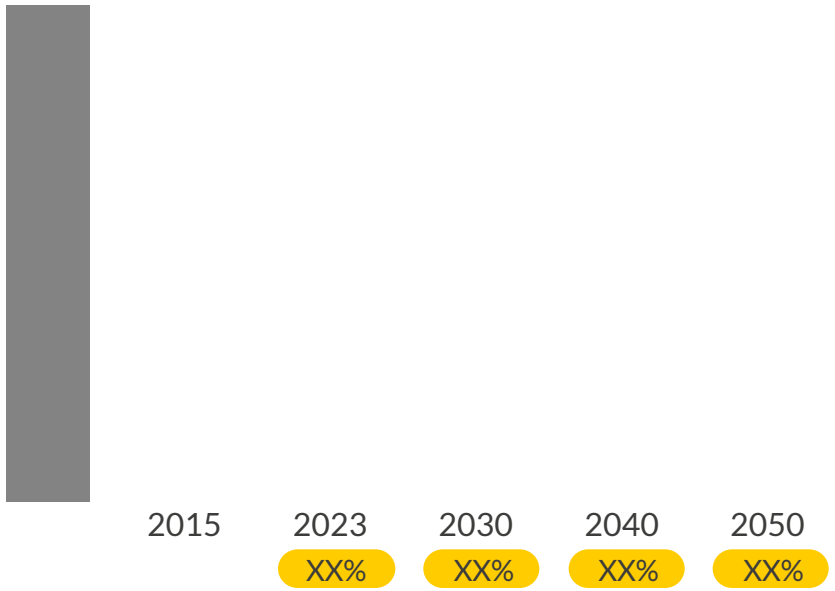


1) Growing demand could improve business case for storage if it is inflexible demand; but if it is flexible demand then detracts from business case for grid scale batteries; 2) Increase in constraint management is further driven by RES deployment outpacing grid capacity

Source: Aurora Energy Research

1 Europe could see a [redacted] GW increase in variable renewables capacity by 2030, accounting for [redacted] % of total generation

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



- Europe's installed capacity of solar, onshore and offshore wind grows over [redacted] times between 2023–2050 in Aurora's Central scenario[3], resulting in an increase in the RES share of generation to [redacted] % and [redacted] % by 2030 and 2050.
- The increase in renewables generation will lead to more variability in generation, creating a need for flexible supply and demand technologies.

Installed variable renewable[1] capacity by 2030 (Aurora Central Scenario), GW

Offshore Wind[2] | Solar PV | Onshore Wind | Total capacity | xx% Variable RES share of generation[4] | XX 2030 capacity, relative to 2023 (GW)

Source: Aurora Energy Research

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

Evolution of conventional generation in Europe[1]
TWh

Peak demand
GW

Source: Aurora Energy Research

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

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National coal phase-out legislation and impacts on battery opportunities

Country	Status of coal phase-out

National outlook for nuclear and impacts on battery opportunities

Country	Status of nuclear policy

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

2 Reducing baseload capacities and slow grid reinforcements lead to an increased need and opportunity for batteries

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Source: Aurora Energy Research.

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

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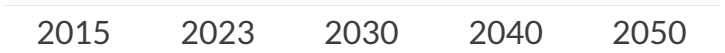
	Objective	Methods
1 Frequency (Response)	System frequency is required to ensure proper system function. Deviations from standard must be corrected in a timely fashion	Automatic dispatch of ultra-fast increase or decrease of energy in real time determined by deviations in the system frequency
2 Energy 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
3 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
4 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
5 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
6 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
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 synchronous generation on the system, Procurement of long term SCL contracts e.g.. through the Stability Pathfinders in Great Britain

Sources: Aurora Energy Research, National Grid

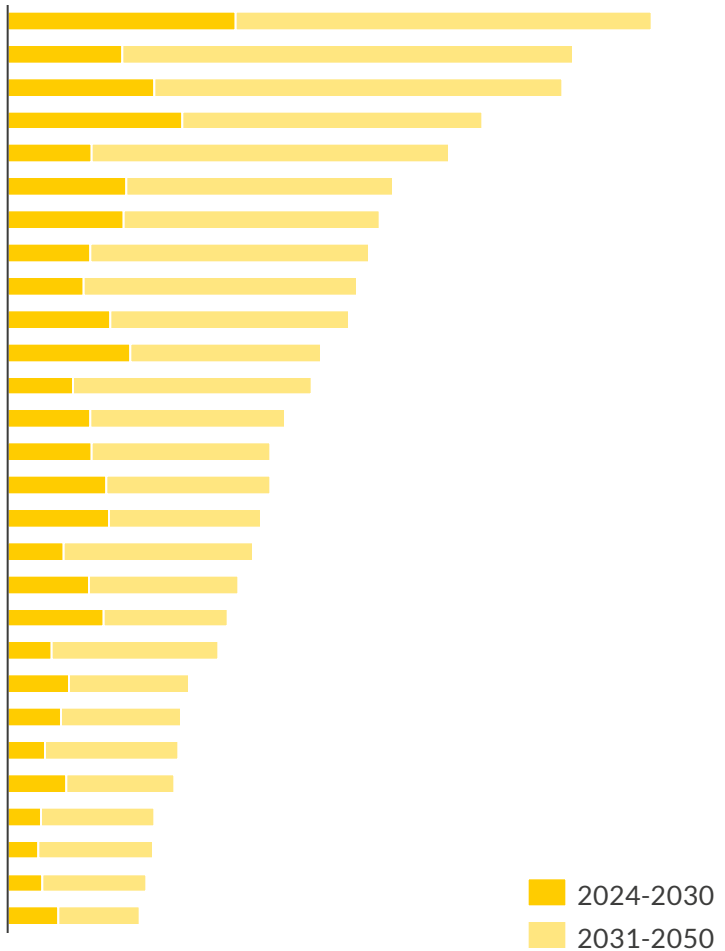
3 Power demand in Europe is expected to increase by [redacted]% to 2050, driven by increased electrification across sectors

Annual power demand in Europe (Aurora Central scenario)[1]
TWh



- In Aurora's Central outlook, European power demand increases by [redacted]% to 2030 and [redacted]% to 2050. Hydrogen makes up the largest share of new demand, followed by electric vehicles, electrification of industry (included in base demand) and heating.
- [redacted] TWh of electricity [redacted]% of demand) in 2050 is used by electrolysers to produce green hydrogen, largely for consumption in industrial processes.

Percentage growth in demand by 2050[1] relative to 2023
%



Historical | Base power demand[3] | Heat | Road transport | Hydrogen

1) EU27 plus Great Britain and Norway, minus Malta and Cyprus; 2) Demand for green hydrogen production from electrolysis; 3) Underlying demand excluding heat and EVs. 4) Aurora Central Scenario.
Sources: Aurora Energy Research, Eurostat

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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

1) Residual demand is defined as 'inflexible generation (wind, solar, biomass, run-of-river, hydro, tidal, nuclear) minus "base" demand (i.e. excluding electric vehicles, electrolysers, flexible heat pumps)
Source: Aurora Energy Research

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

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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Operational Pipeline[4]

1) Largest known project 2) CAPEX numbers are in terms of today's costs, and they are calculated assuming the supply and commissioning costs. 3) While Li-ion battery technology is very mature, few long duration (8hrs +) Li-ion projects have been built at commercial scale yet. 4) Includes EPC, grid connection, balance of system and development costs. 4) Includes in construction and pre-construction. Limited public information available on the pipeline of flow /sodium batteries due to their typically small scale.

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

The cost of developing grid-scale batteries is made up of various components

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Total Project Cost

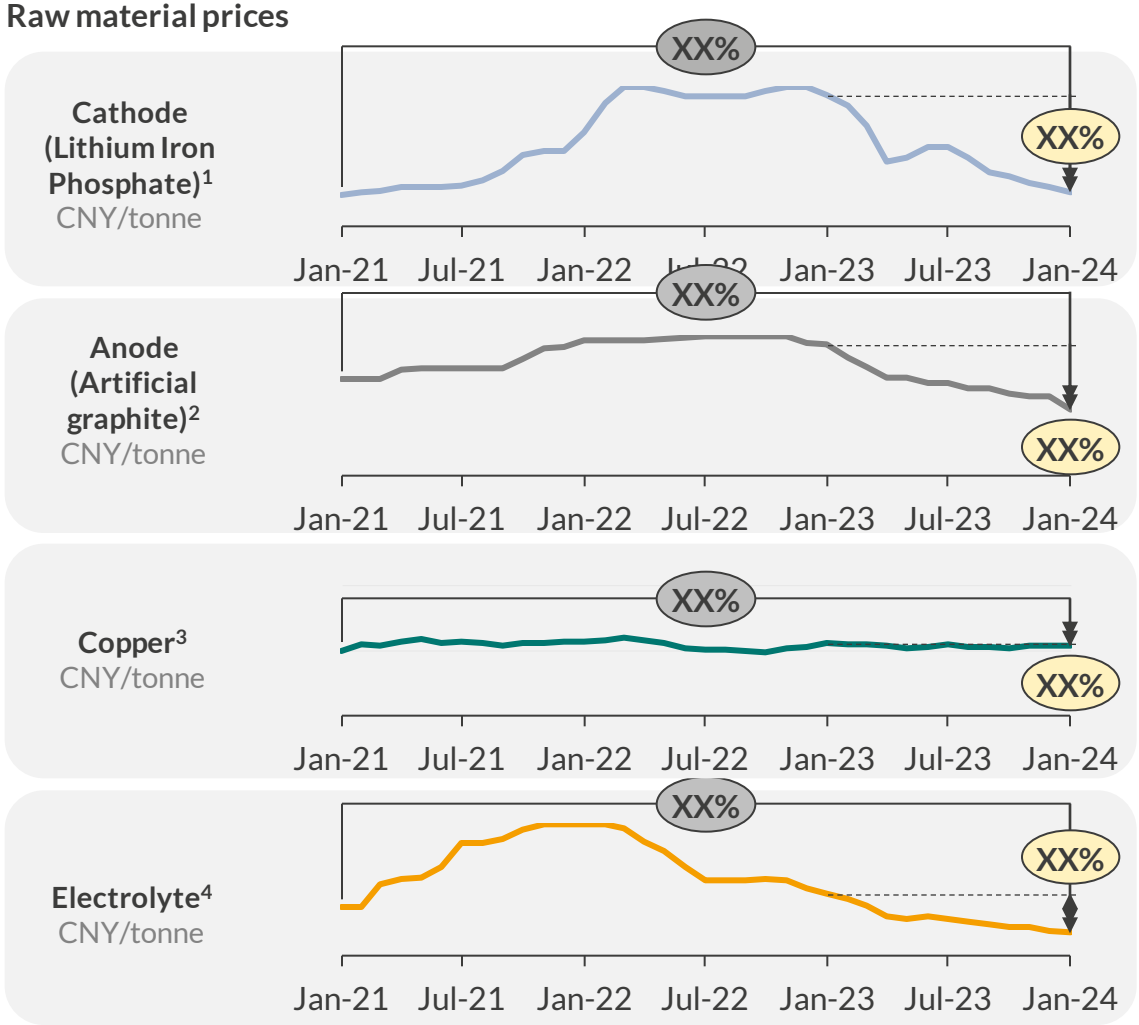
Battery system	Electrical and structural BoS[1]	EPC[2] soft costs	Connection costs	Development costs
Containerised[3] battery storage systems; main components include: ▪ **Cells** – anode, cathode, electrolyte. and separator system ▪ **Modules** – collection of cells put into an external frame for protection from. external interference ▪ **Battery, thermal and energy management systems** – protect batteries by ensuring they operate within safe limits, and control operation ▪ HVAC[4], fire suppression, racking	Components external to the battery containers, including: ▪ **Inverters (i.e., power conversion)** – used to switch from AC to DC during charging and DC to AC during discharge; typically, a major component of the BoS cost ▪ Control, monitoring and protection components. ▪ Other electrical BoS – cabling, auxiliary power supply etc ▪ Structural elements of site e.g.., foundations, fencing	Costs of designing and constructing the site, including: ▪ Engineering consultants – electrical engineers, project manager and other specialists ▪ Construction labour – electrical and structural ▪ Overhead and profits for construction contractors ▪ Commissioning	Costs to set up electrical connection to distribution or transmission network[5], including: ▪ Design activities ▪ Laying of new cables ▪ Transformers ▪ Upgrades to existing substations, etc Costs vary according to: ▪ Transmission vs distribution network ▪ Voltage level ▪ Region / country ▪ Characteristics of local network (e.g.., whether site causes need for local substation upgrades)	Costs involved in development to project developer including: ▪ Project origination and acquisition ▪ Connection and planning studies and applications ▪ Land acquisition and control ▪ Developer overhead and profit

1) Balance of System; 2) Engineering, Procurement and Construction; 3) Typically ~40ft containers of ~2MWh capacity; 4) Heating, ventilation and air conditioning; 5) Inclusive of all contestable works (can be undertaken by network operator or independent provider) and non-contestable works (can only be undertaken by network operator)

Sources: Aurora Energy Research, NREL, O. Schmidt et al, IRENA, STA, ADB, McKinsey and Company

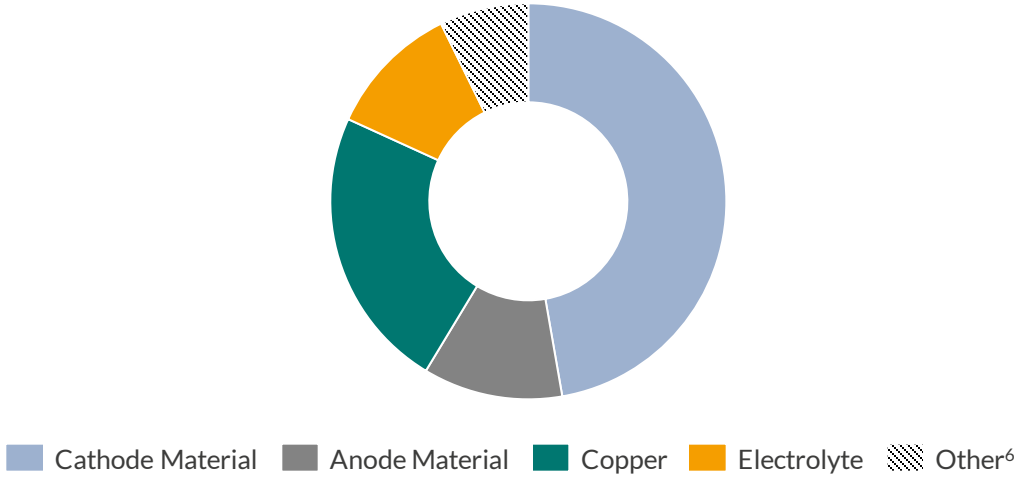
Anode, cathode and electrolyte prices decreased over [redacted]% since the start of 2023, while copper prices fluctuated minimally

Raw material prices



Battery System Raw Material Components[5]

By value



- Cathode prices experienced a sharp increase in 2022. But the trend has reverted since January 2023 due to 1) oversupply of lithium, 2) weak demand for EVs, 3) battery manufacturers pushing to depress raw material prices.
- After a rise in early 2022, graphite prices remained at a high plateau but began to drop since Jan 2023. Electrolyte price also dropped by [redacted]% since the start of the year. Copper price remains relatively stable compared to the past year.
- Both cathode and electrolyte use raw materials that are derivatives of Lithium Iron Phosphate as a main raw material. The decreasing spot price of Lithium is therefore linked to the decrease in the overall CAPEX.

1) Lithium Iron Phosphate price; 2) Artificial graphite (mid-level) price; 3) Copper spot price plus labour cost on processing copper foil; 4) Electrolyte's main component is Lithium hexafluorophosphate; 5) Illustrative material weight split for Lithium-Iron Phosphate (LFP) batteries which are the current dominant technology in Europe's stationary storage markets; 6) Other category includes aluminium and other structural materials used to construct battery pack..

Sources: Aurora Energy Research,, MySteel, UK Investing

Supply chains for Lithium-ion batteries are dominated by China; US is gearing up to increase market share while Europe lags

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Lithium-ion battery cell manufacturing capacity by region
% of total manufacturing capacity

Policy support for battery manufacturing in the US and Europe

XX Global manufacturing capacity (TWh)

1) From REPowerEU, the Recovery and Resilience Facility, the Innovation Fund as well as Invest EU. In November 2023, the EU's Innovation Fund announced that €1.4 billion in grant funding – double the previous year's budget - will be made available for projects manufacturing clean-energy components, including for batteries.

Sources: Aurora Energy Research, IEA

Aurora applies learning rates from historical battery cost reductions and key raw materials price movements to forecast CAPEX

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Aurora's battery CAPEX follows a three-step approach for long-term and short-term cost forecasts

Long-term

1 Historical data available to Aurora on CAPEX by cost component is compiled for 1h, 2h and 4h duration battery systems

- CAPEX on new-build costs are aggregated from a combination of client quotes, benchmarked with market research and historical cost outturns. Base values are reflective of installation costs in 2021.

2 Expected learning rates for each cost component are applied to reflect technological improvements from economies of scale

- Learning rates are obtained from market research of historical battery cost reductions and checked against publicly available sources and views from key stakeholders.

3 Aurora's cost model combines expected learning rates and CAPEX quotes to arrive at forecasted CAPEX reductions

- The forecasted global deployment of battery storage systems in combination with expected learning rates per cost component are used to project future cost reductions.

Short-term

1 Prices of key raw materials in the previous 6 months, as well as expected demand and supply trends, are surveyed biannually

2 Short-term uplift in CAPEX relative to the base year of available data is calculated, combining price trends and cost contributions by material

3 This short-term uplift is blended into the long-term CAPEX outlook, accounting for expected material supply and demand trends

Other assumptions include modelled battery chemistry and variations between countries

Battery cathode chemistry	• CAPEX forecasts assume a Lithium Iron Phosphate (LFP) cathode chemistry. This is typical for a stationary storage use-case, as LFP chemistries are generally cheaper but lower in energy density compared to other cathode chemistries. For an electric vehicle use-case that necessitates higher energy densities, other more expensive cathode chemistries (such as NMC cathodes) are a more suitable benchmark.
Localisation	▪ CAPEX components that are location-dependent (such as business rates and grid connection costs) are revised independently by country teams to more accurately reflect cost differences between countries.

Source: Aurora Energy Research

Quickly falling commodity prices in 2023 results in battery system CAPEX resolving to Aurora's long-term battery cost outlook

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Li-ion battery total system costs – 2h asset
€/kW real 2022

CAPEX changes by component from 2023 to 2030
€/kW, real 2022

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Development Connection EPC Balance of system Inverter Battery system Historical costs

Source: Aurora Energy Research, NREL ATB

Battery CAPEX decline by [redacted]% by 2030 due to technology progress and economies of scale in production

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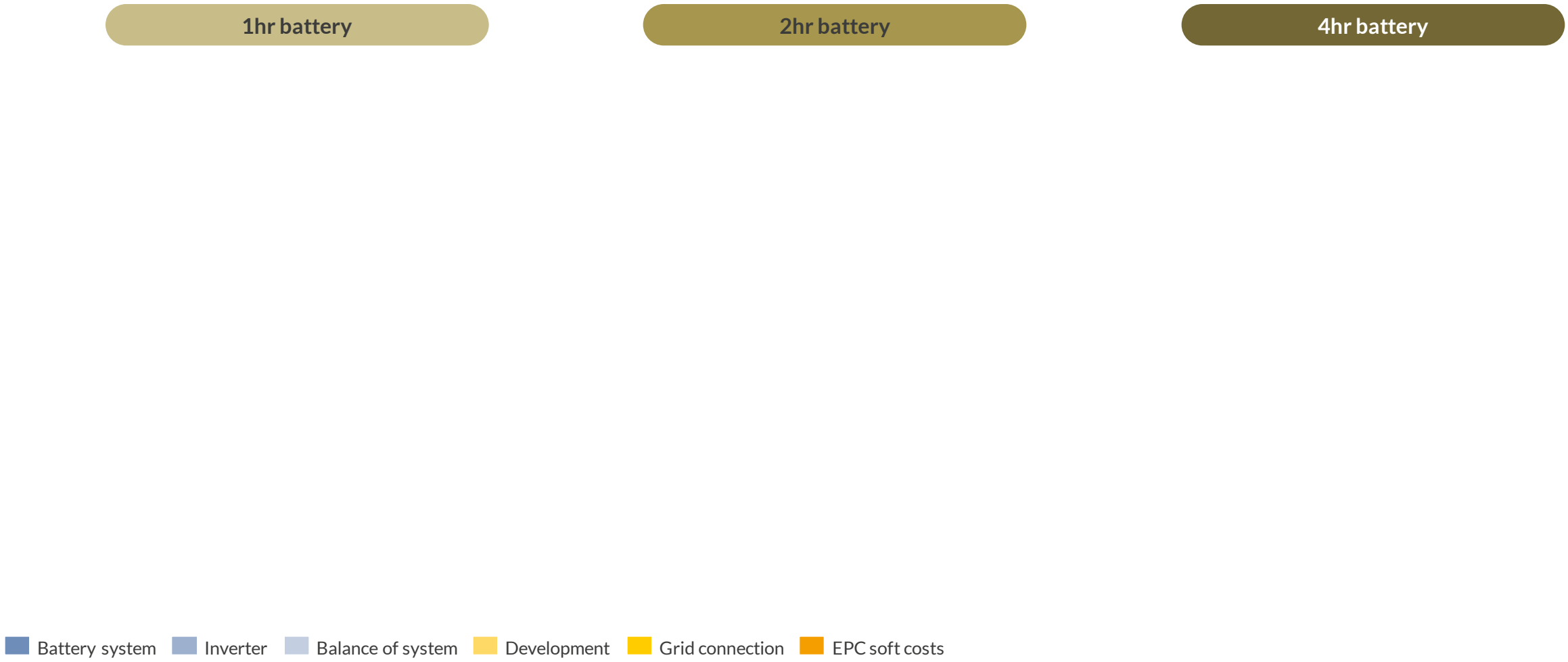
Battery storage CAPEX, by duration[1]
€/kW (real 2022)



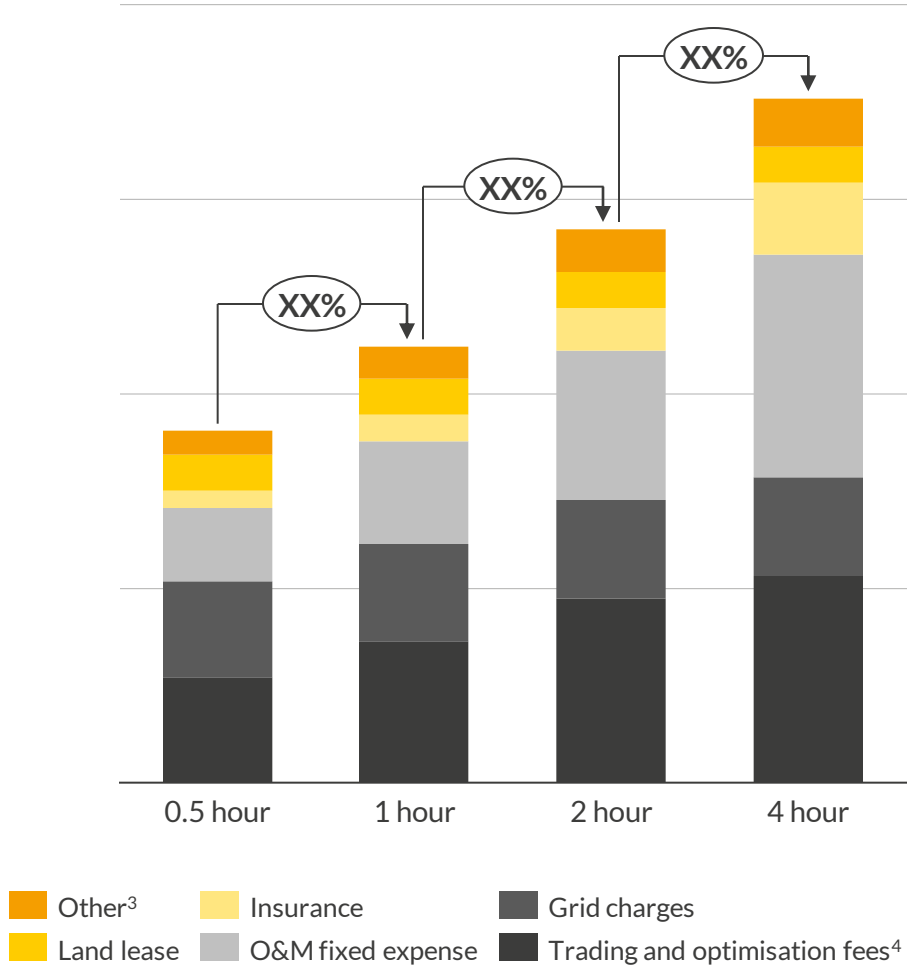
1) Representative average stationary battery cost for Europe

Sources: Aurora Energy Research

Ongoing fixed costs include route-to-market fees, grid charges, O&M, insurance, and land lease

Component	Description
Trading and optimisation fees	Charges for electricity trading on wholesale and balancing markets as well as optimisation fees for use of software or external providers managing optimised battery use
Grid charges	Can vary significantly depending on site and in case local upgrades to distribution grids are required. Typically paid either as annual capacity charge or per kWh exchanged with the grid
O&M fixed expense	Includes costs such as scheduled maintenance, performance monitoring and extended performance guarantees.
Insurance	Can include liability, environmental, property, and other insurances such as cyber security etc.
Land lease	Agreement allowing use of land in exchange for rent
Other	Covers cost such as auxiliary load, admin, communication and other small costs

Fixed costs breakdown by duration[1,2] – central assumption
€/kW/year, real 2022



1) OPEX shown for 2023 operational year. 2) OPEX shown exclude property taxes. The reason is that we calculate pre-tax IRR for better comparability across markets; 3) Includes admin charges, communications and other small costs; 4) Trading and optimisation fees may have both fixed and variable elements but are represented here as a single fixed charge.
Sources: Aurora Energy Research

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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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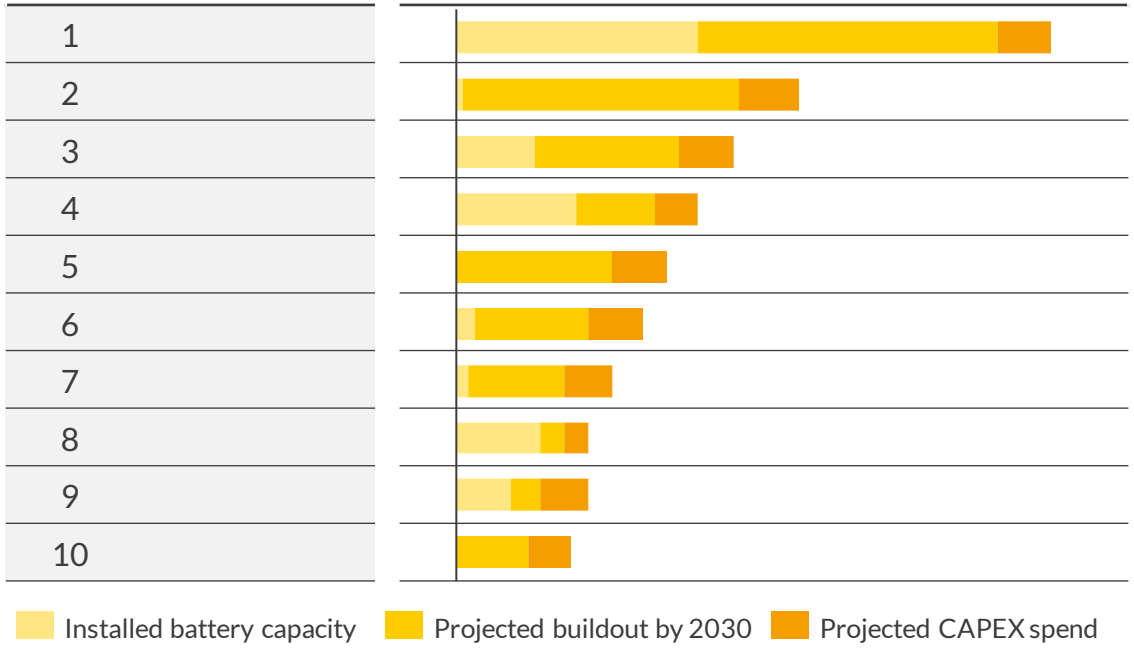
Market size and outlook

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 Current installed battery capacity	40%	Indicates current market size[1]
2 Projected battery buildout by 2030	50%	Indicates expected future market size[1] in the medium term, based on Aurora's Central scenario
3 Projected CAPEX spend until 2030	10%	Indicates expected future investment need, accounting for required battery durations and repowering

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



Source: Aurora Energy Research

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Total battery storage in Europe reached over [redacted] GW in 2023; the developer and investor landscape for assets is fragmented

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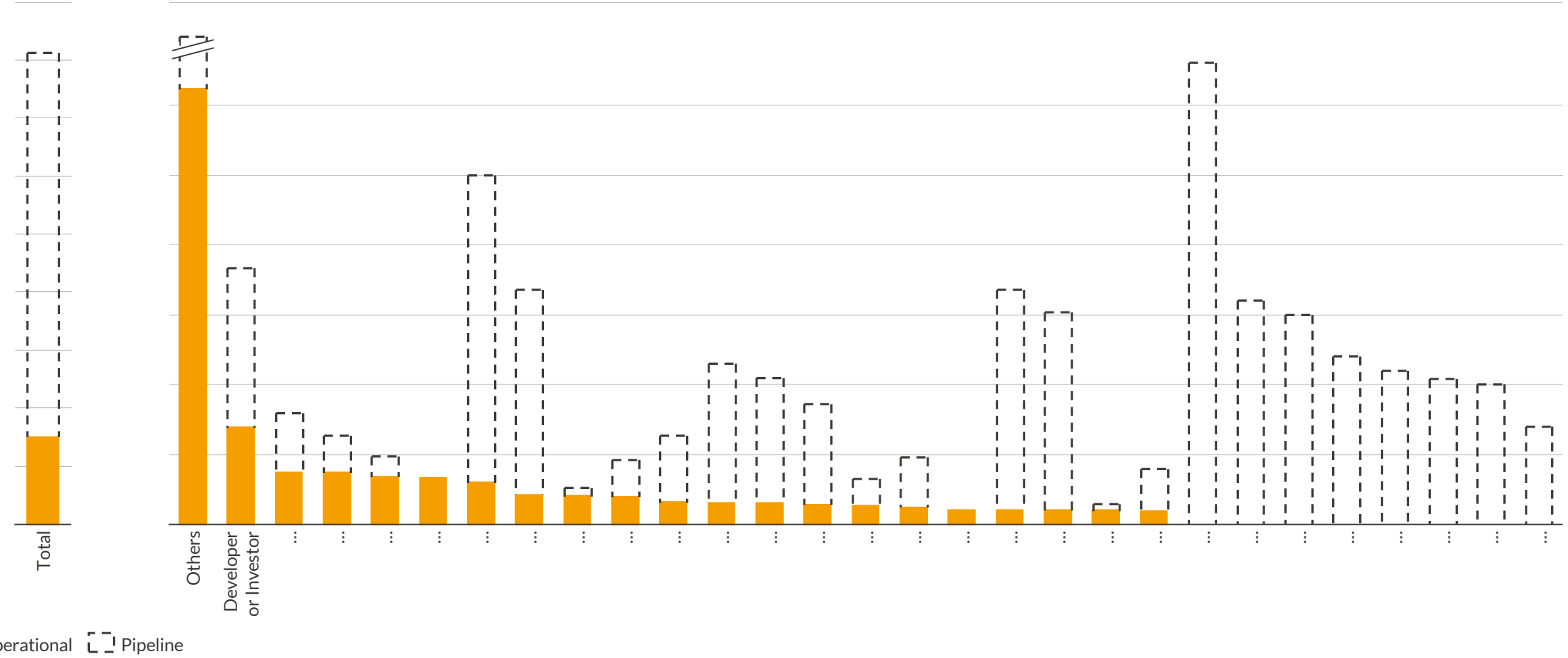
Battery capacity by leading energy storage developers/investors in Europe[1]
MW



Sources: Aurora Energy Research,

Full delivery of the current pipeline would see battery capacity in Europe grow fourfold to [redacted] GW by 2026, a ~ [redacted] GW increase

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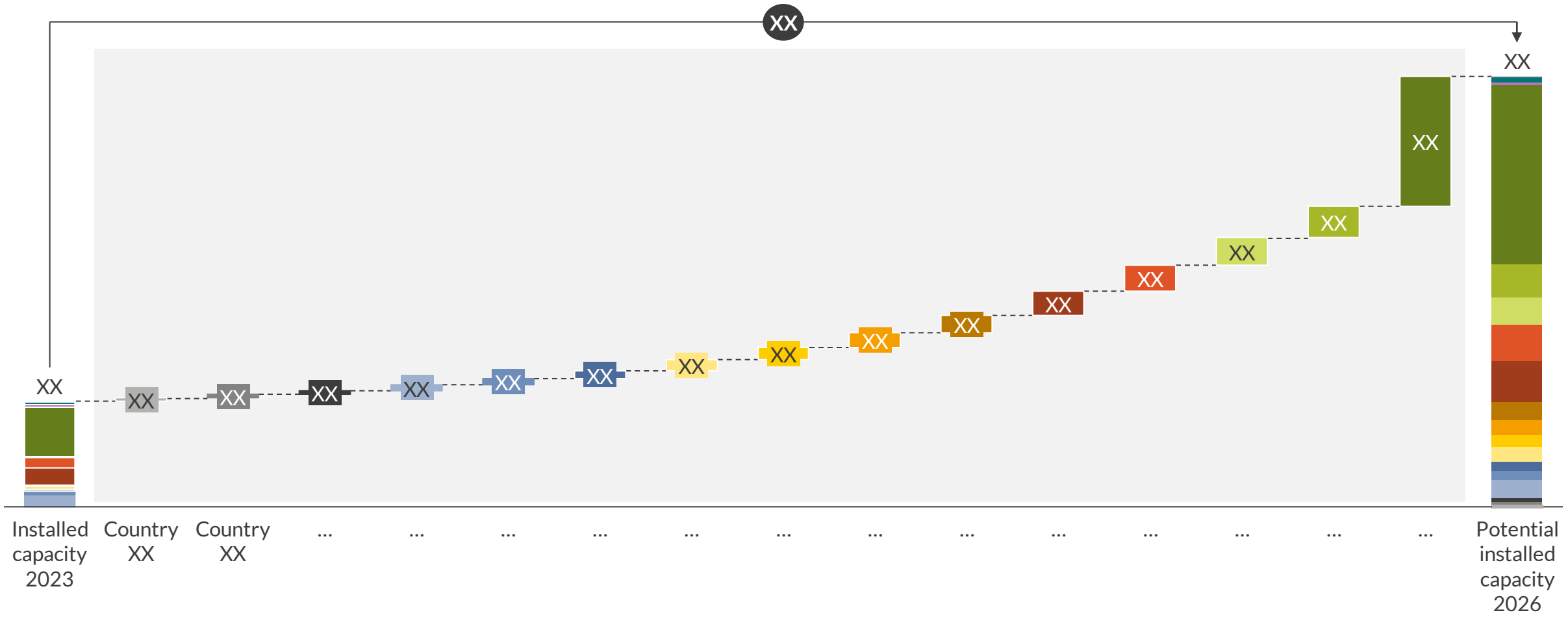
Near-term project pipeline of grid-scale batteries[1]
GW, nameplate



Sources: Aurora Energy Research

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

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Battery suppliers and integrators	Route-to-market providers

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1) Non-exhaustive list of integrators for known operational European batteries. 2) Non-exhaustive list. 3) Other European countries including Poland, Greece, Hungary, Slovenia, Serbia, Romania, Croatia, Bulgaria, Lithuania, Latvia, Estonia.

Sources: Aurora Energy Research

Asset owners have different route-to-market options to manage a desired risk profile

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1 Route-to-market (RtM) providers offer third-party optimisation and risk management services to asset owners, with different commercial clauses impacting the owner's merchant risk exposure

Price clauses		Merchant risk exposure
Commercial Clause	Description	Battery owner → Trader

2 Providing service at lowest cost typically drives competition between RtM providers, but growing focus on optimisation capability is expected as the complexity of markets expand, and business models shift more to energy trading

Distinguishing features of RtM providers

1) Balancing Service Provider/Balancing Responsible Party.

Sources: Aurora Energy Research

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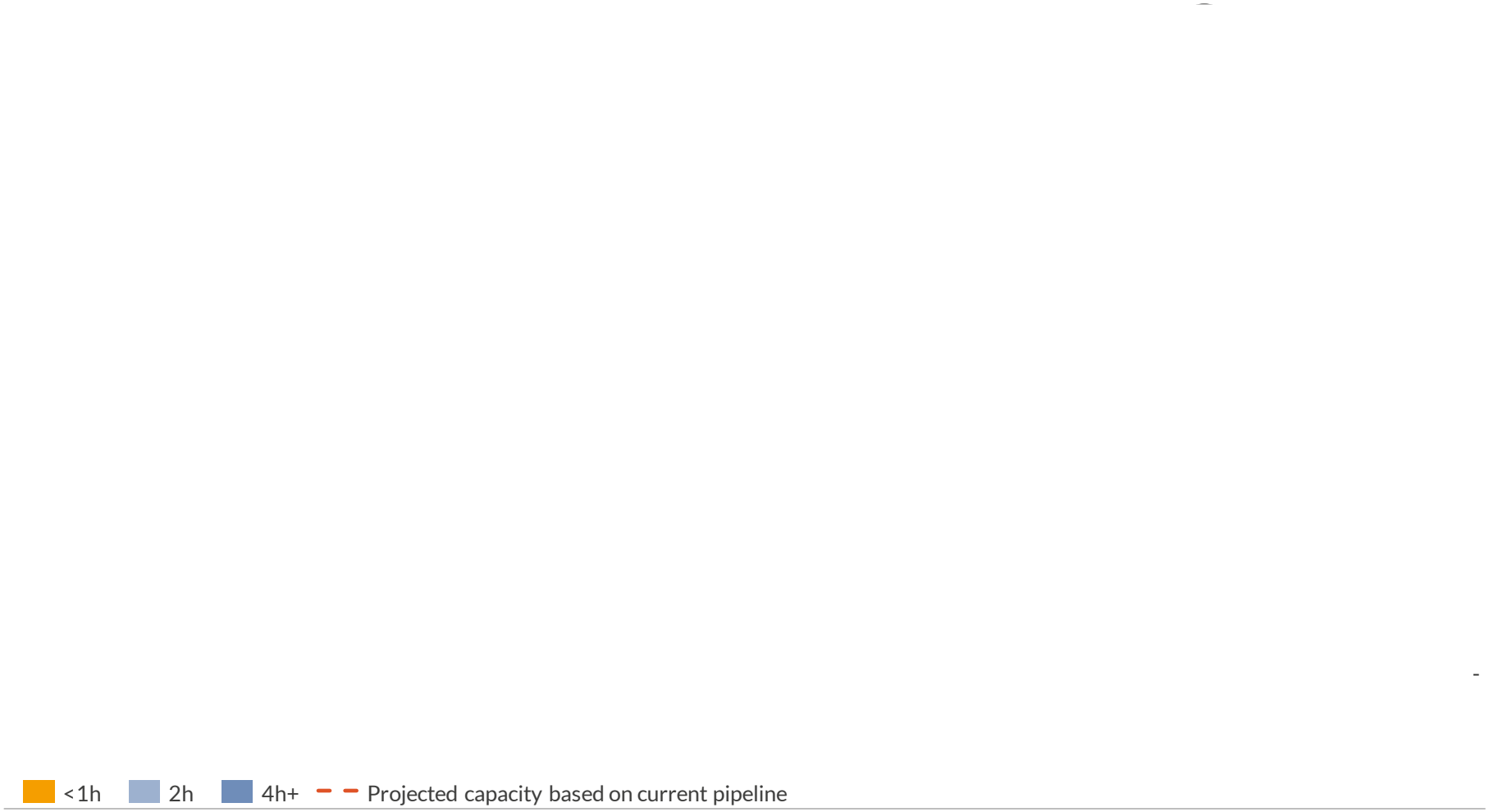
Based on Aurora's Central scenario, grid scale battery storage could grow to [redacted] GW by 2030, [redacted] GW more than the current pipeline

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



Sources: Aurora Energy Research, Eurostat

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Aurora's 2030 forecasted capacity denotes over [redacted] GW of capacity additions from 2023, mainly deployed in [redacted], [redacted], and [redacted]

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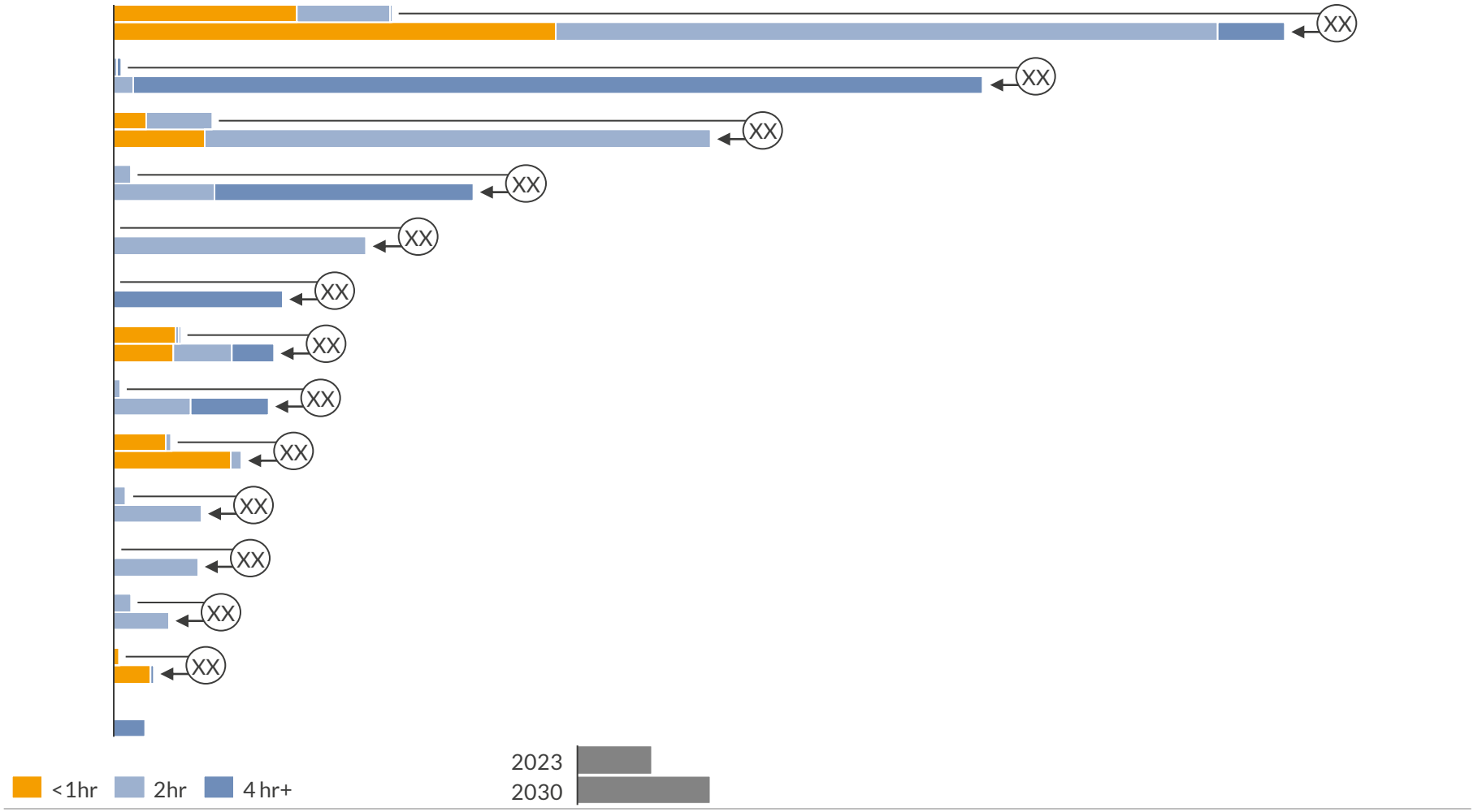
Installed battery capacity in 2023 and 2030 (Aurora Central scenario)

GW



Sources: Aurora Energy Research, Eurostat

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The projected battery capacity additions represent a cumulative investment opportunity of over [redacted] bn€ between 2023-50

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Total CAPEX spent on grid-scale batteries
bn € (real 2022)

2024-30 2031-40 2041-50

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1) EU27 plus Great Britain and Norway, minus Cyprus and Malta.

Source: Aurora Energy Research

Though deployment of behind-the-meter (BtM) batteries could drive competition, growth of grid-scale batteries is expected to be faster

Historical and forecasted capacity of behind-the-meter and grid-scale battery storage systems across Europe
GW

1) Based on Aurora Central scenario. 2) Assumes average duration of 2 hours.

Sources: Aurora Energy Research, Eurostat, SolarPower Europe, CleanTechnica

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Smart charging systems could drive competition for grid scale assets with [redacted]x more smart charging EV storage than grid storage by 2030

Total available storage in electric vehicles (EVs) in Europe (Aurora Central scenario)
GWh

EVs avaliable for smart charging[1] Utility-scale battery storage XX Storage capacity of smart[1] EVs as multiple of grid scale batteries (GWh)

1) Refers to unidirectionally smart charging vehicles i.e. vehicles that can adapt the timing of their charging based on power prices. V2G refers to bidirectional charging vehicles. 2) See slide 69

Sources: Aurora Energy Research, Eurostat

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Executive Summary

Policy and regulatory environment

1) National Energy and Climate Plans.

Source: Aurora Energy Research

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

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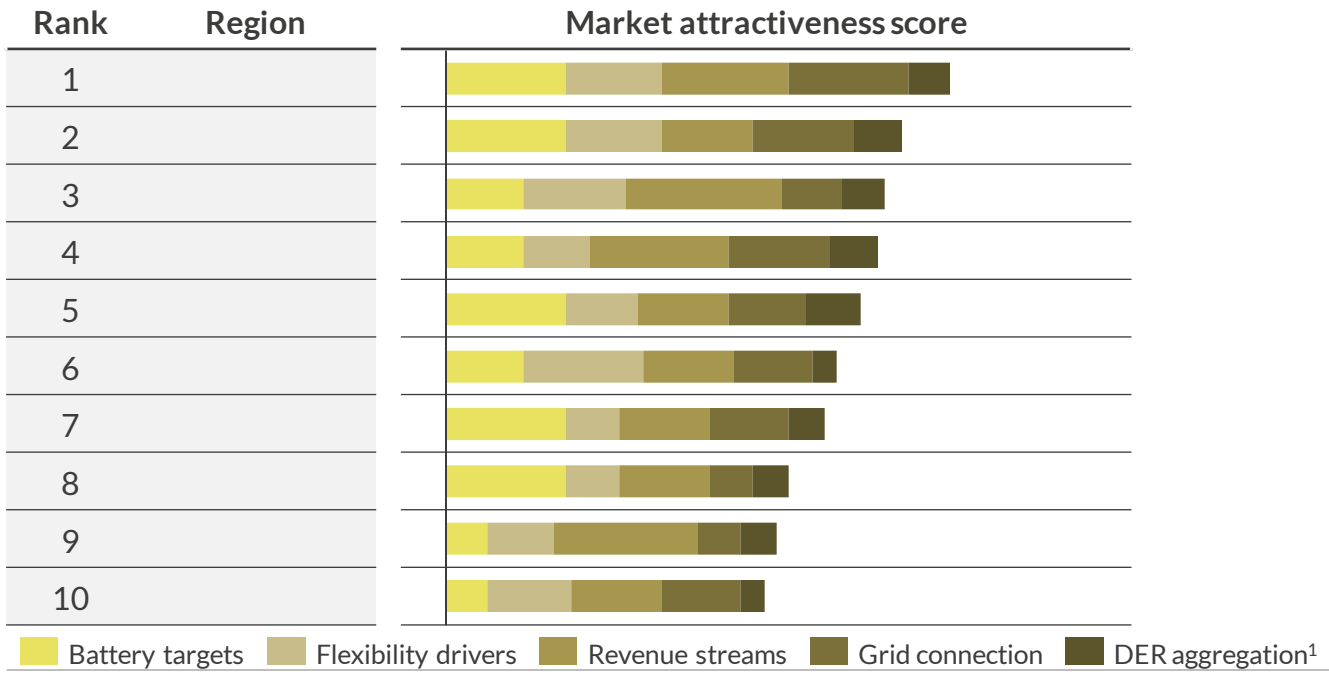
Policy environment

Countries are assessed in terms of their policy environment for battery storage as of Q1 2024, based on five 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 National battery targets and policies by 2030	*20%*	Demonstrates policy ambition for battery storage deployment
5 Renewables targets (i.e. driver of flexibility needs)	*20%*	Demonstrates policy ambition for renewables deployment
6 Availability and contractability of revenue streams	*30%*	Indicates availability and long term contractability of revenues
7 Risks from grid connection and charges	*20%*	Indicates regulatory risks around grid connection and charges
8 Competition risks	*10%*	Indicates competition risks around aggregation[1], electrolysers and EVs



1) Distributed energy resources

Source: Aurora Energy Research

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The outlook for battery storage deployment is largely driven by energy policy and regulation

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	A Emissions policies	B Policy strategies and targets for battery storage	C Availability and stack-ability of revenue streams	D Regulatory risks
Description	▪ 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.	▪ Country policies regarding energy storage shape the development of their systems and influences buildout. ▪ It indicates government support and commitments to capacity deployment	▪ Indicates the availability of diverse revenue streams ▪ Highlights the stack-ability of the revenues streams as enabled by policy and regulation	▪ 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.
Implications	▪ 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.	▪ 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.	▪ 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.	▪ 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.

Source: Aurora Energy Research

Across Europe, many countries have set ambitious renewables targets, driving increased requirements for batteries

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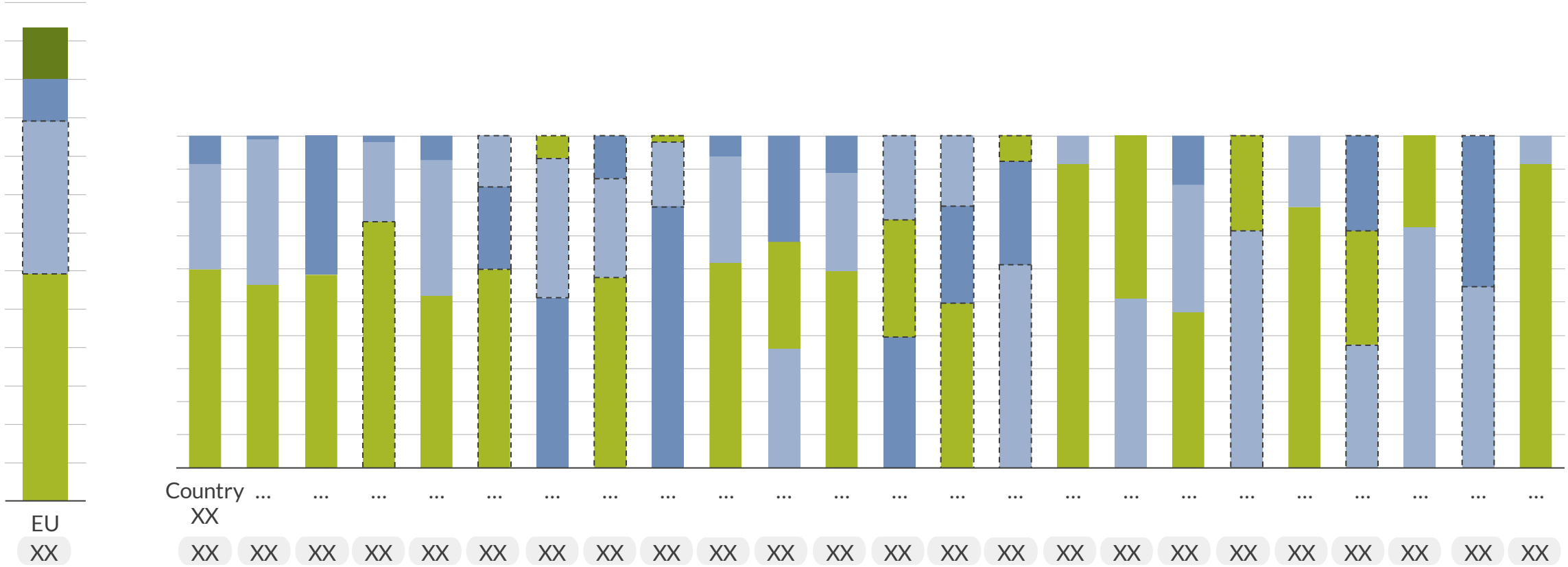
Target RES installed capacity by 2030
GW



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

Policy support for battery storage at the EU level is not yet mature, and recent developments focus more on the upstream value chain

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- **TERRE** project approved by ENTSO-E as an Implementation Project and to become the European platform for the exchange of balancing energy from replacement reserves
- International Grid Control Cooperation (IGCC) chosen by ENTSO-E as the implementation project to become the European Platform for the imbalance netting process

Guideline on Electricity Balancing (GL EB):

- Provided the introduction of platforms to enable the exchange of balancing energy from frequency restoration reserves and replacement reserves
- Memorandum of Understandings signed for PICASSO and MARI projects

Clean Energy package:

- Rulebook introduced to achieve European Green Deal objectives
- Role of battery storage acknowledged for the first time as crucial for integrating renewables and enhancing energy security amongst others
- Included proposal to define a new regulatory framework to support batteries

Renewable Directive (RED III):

- Stipulated that system operators cannot own or operate storage facilities to increase competition and ensure fair access to storage facilities for all market participants
- Prohibits discrimination of storage compared to other technologies

Strategy for Energy System Integration:

- Stipulated that "double charging" of fees for using the grid should not be applied to energy storage

New regulation on design, production and recycling[1]:

- Requirements for recycling at end of lifetime, recovery of minerals (especially lithium) and use of recycled minerals in manufacturing of new batteries
- Addresses environmental risks linked to batteries

Green Deal Industrial Plan:

- Industrial strategy to support net-zero industry, including for batteries
- Propose to revise State aid rules to allow aid for the production of batteries and related critical raw materials

Recommendations on energy storage[2]:

- Outlines recommended policies to promote energy storage, such as defining of flexibility needs in NECPs, identifying need for additional financing instruments or remunerated markets and facilitating permit-granting procedures.

1) EU Battery Regulation Amendment (Sustainable Batteries Regulation). 2) Recommendations on energy storage.

Sources: Aurora Energy Research, European Commission

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

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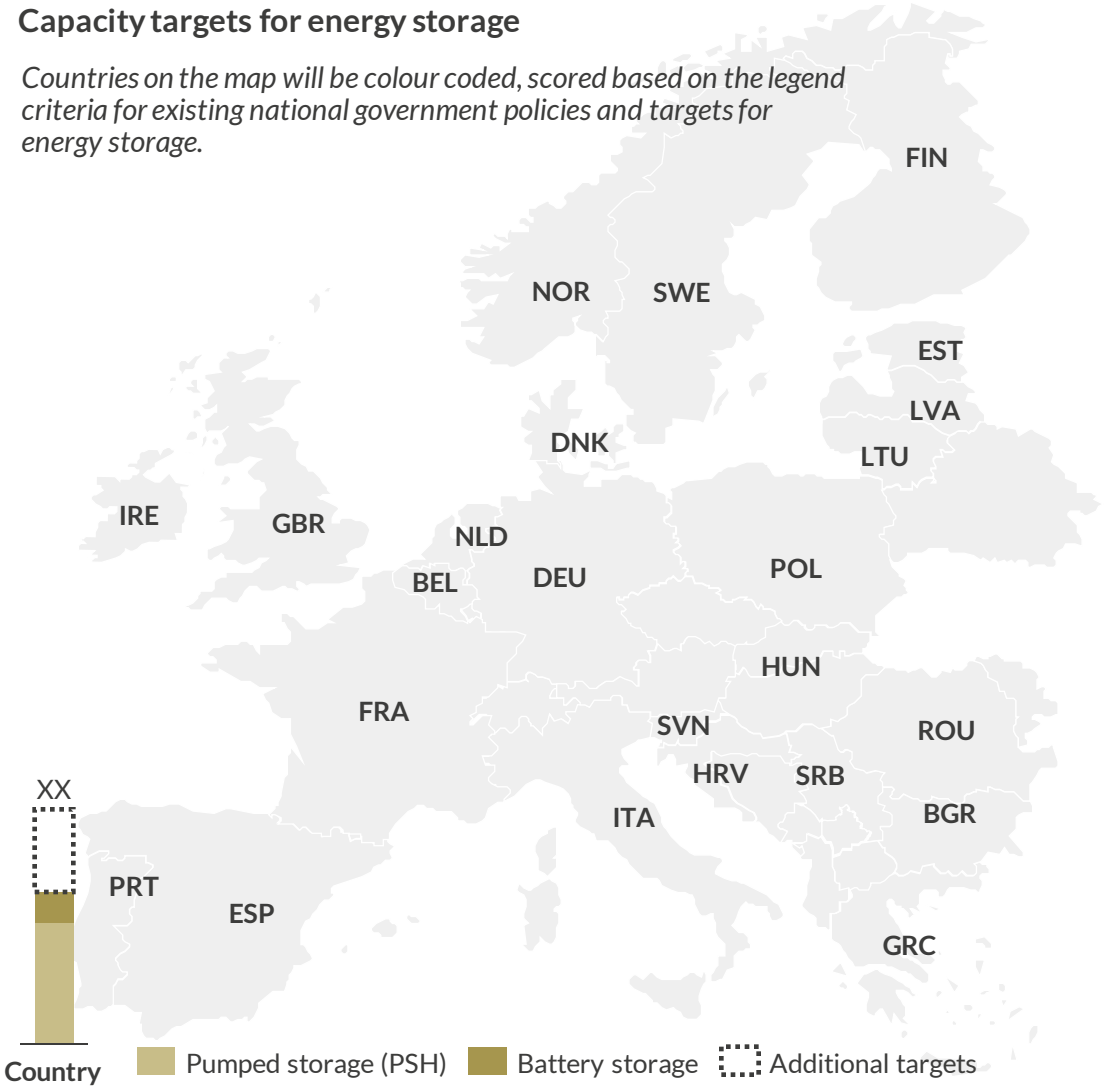
Capacity targets for energy storage

Countries on the map will be colour coded, scored based on the legend criteria for existing national government policies and targets for energy storage.



National government policies and targets for energy storage

Legend		Policies and targets
1	No specific strategy/plan	*Country:* [redacted]
2	Strategy or plan for capacity deployment in place, but without commitments and not legislated (eg, non-binding or TSO targets only)	*Country:* [redacted]
3	Strategy or plan for battery capacity deployment in place with strong commitments e.g. legislated in policy, through auctions or National Energy and Climate Plans (NECP)	*Country:* [redacted]

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)

. Sources: Aurora Energy Research, National Governments, TSOs

Auctions to date have subsidised at least [redacted] GW[1] of batteries in [redacted], [redacted] and [redacted], with [redacted] GW in future procurement

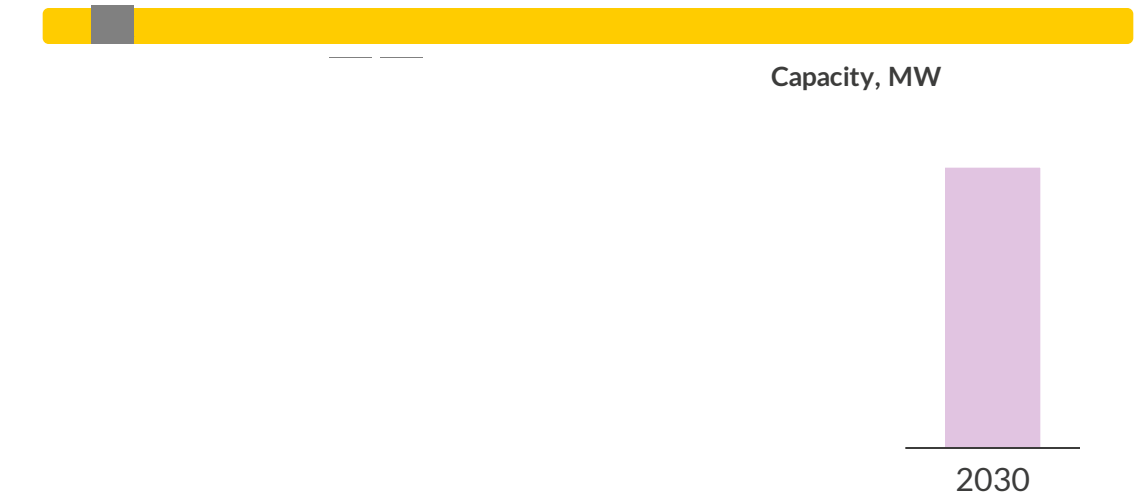
AURORA

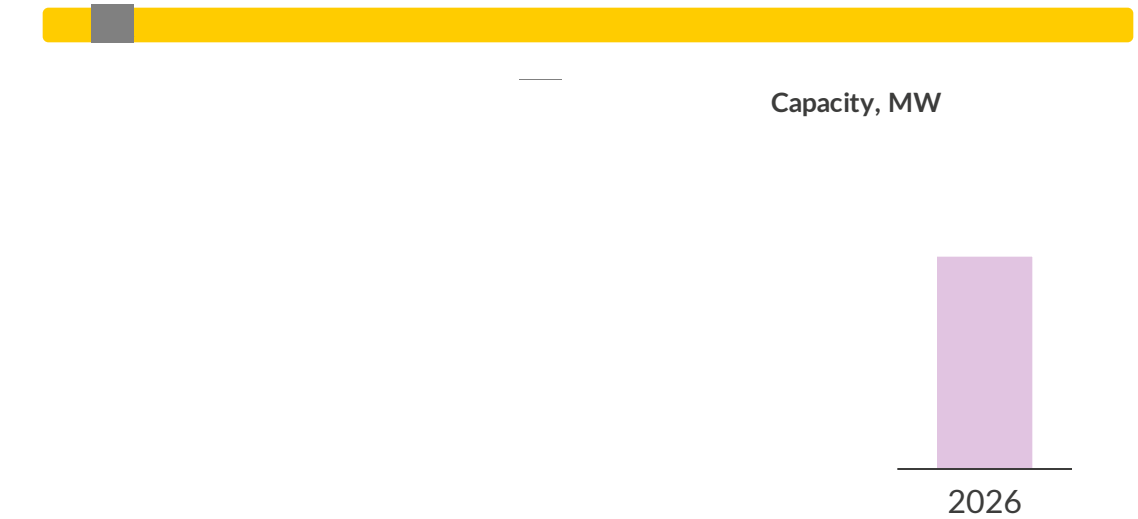
◆ Average accepted bid price ■ Awarded capacity ■ Procurement target ▨ Unconfirmed auctions ⬚ Total bids

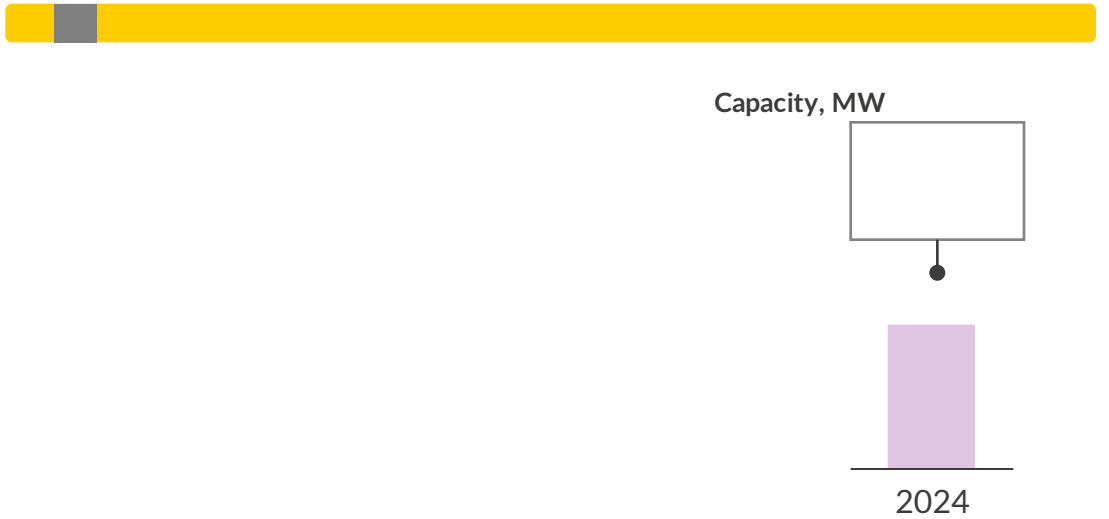
1) Based on awarded capacities and minimum percentages for battery capacity as defined in co-location auction rules.

Sources: Aurora Energy Research

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







Minimum/Maximum support level Procurement target

Sources: Aurora Energy Research, European Commission

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Political agreement was reached on the EU market reform proposal in December 2023, which included a focus on promoting flexibility

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Topic	Key elements of European Commission[1]	X Most relevant to storage	Impact on battery outlook

1) Agreed positions on key elements of the EU power market reform package, as of 17th October 2023. Other key elements included consumer protection legislation and CfD 2) Member states will be granted a transition period of 3-5 years, depending on the technology and its setup. 3) Member states are free to introduce support measures, such as state-backed guarantee schemes or facilities pooling demand to remove potential barriers

Sources: Aurora Energy Research, European Commission

Ongoing regulatory developments within certain markets present both opportunities and challenges for battery assets (1/2)

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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 (2/2)

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Region	Market development	Impact	Impact on battery storage outlook

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Sources: Aurora Energy Research

Grid Integration: Ease of obtaining grid connection and the favourability of grid usage fees are combined into one score

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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

+

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 Integration

Traffic Light Score Legend

1-2	**Poor** grid integration
3-4	**Average** grid integration
5-6	**Good** grid integration

Regulatory hurdles in grid access and fees for batteries across Europe is mixed, complicating the deployment of new capacity

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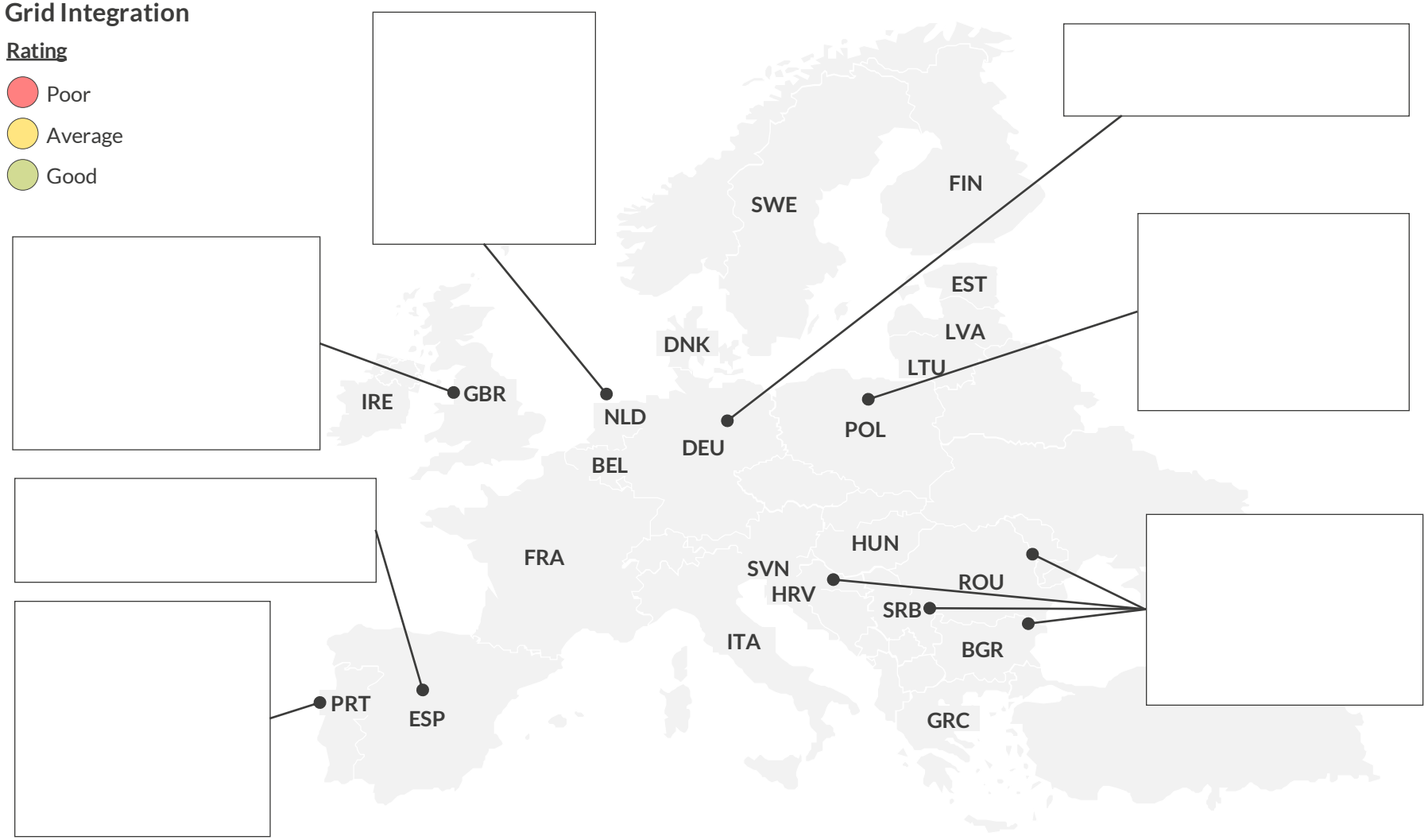

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Sources: Aurora Energy Research

Competitive risk arises from supportive policies on demand-side and BtM aggregation, electrolysers and electric vehicles

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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

Competition risk

Traffic Light Score Legend

3-4	**High** risk
5-7	**Medium** risk
8-9	**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.

[redacted], [redacted] and [redacted] see the highest competitive risk to batteries, where aggregation into ancillary markets is enabled

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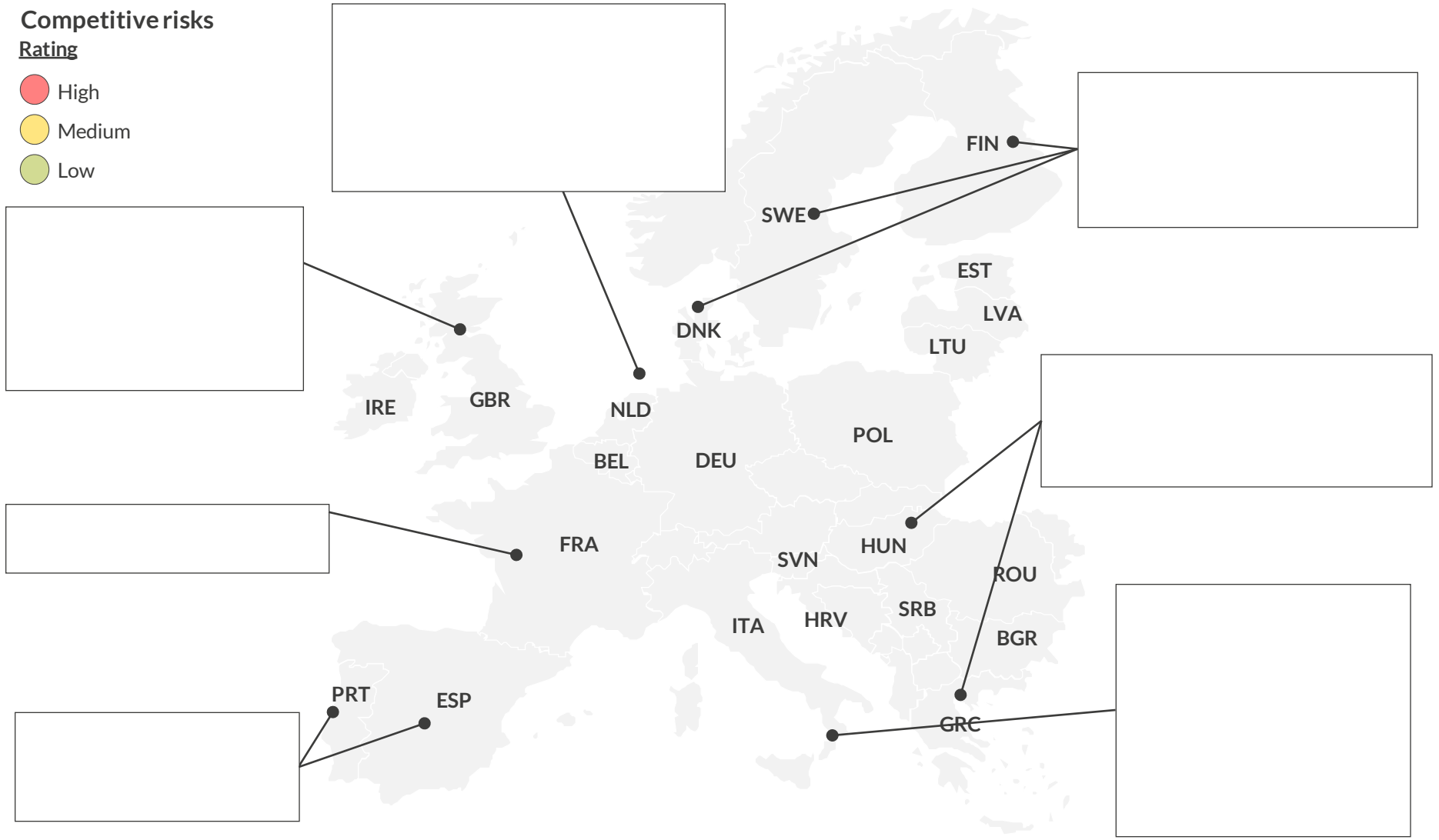

This is a redacted sample of the European Battery Market Attractiveness Report. If you are interested in the full report, contact Alex Hutcheson (alex.hutcheson@auroraer.com)

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

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 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[1]

- Balancing markets and slower frequency response services (e.g. mFRR and Replacement Reserve) ensure balance is maintained in the power system in each daily trading period
- Such services typically have higher and longer-lasting energy requirements
- Batteries can take advantage of arbitrage opportunities and revenues from provision of such services

FR Frequency Response Services[2]

- 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

1) Includes Balancing Mechanisms in Great Britain and Ireland and frequency products with full activation time > 10 minutes such as mFRR, RR, and Secondary/Tertiary Reserves within Italy's MSD; 2) Includes frequency products with full activation time < 10 minutes such as FFR, FCR and aFRR

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

Most countries allow for batteries to stack various revenue streams, however contractual revenues are limited (1/2)

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Sources: Aurora Energy Research

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

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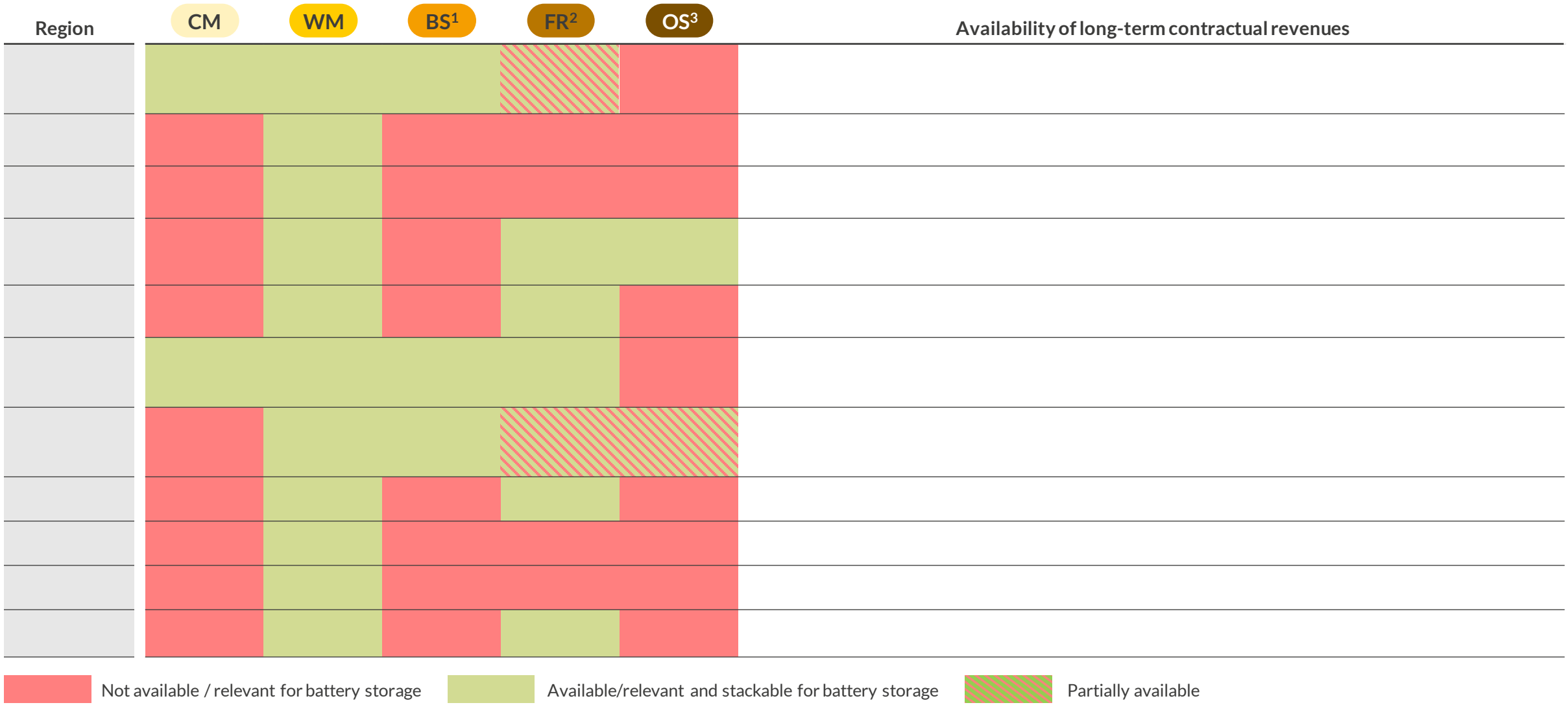

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Sources: Aurora Energy Research

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

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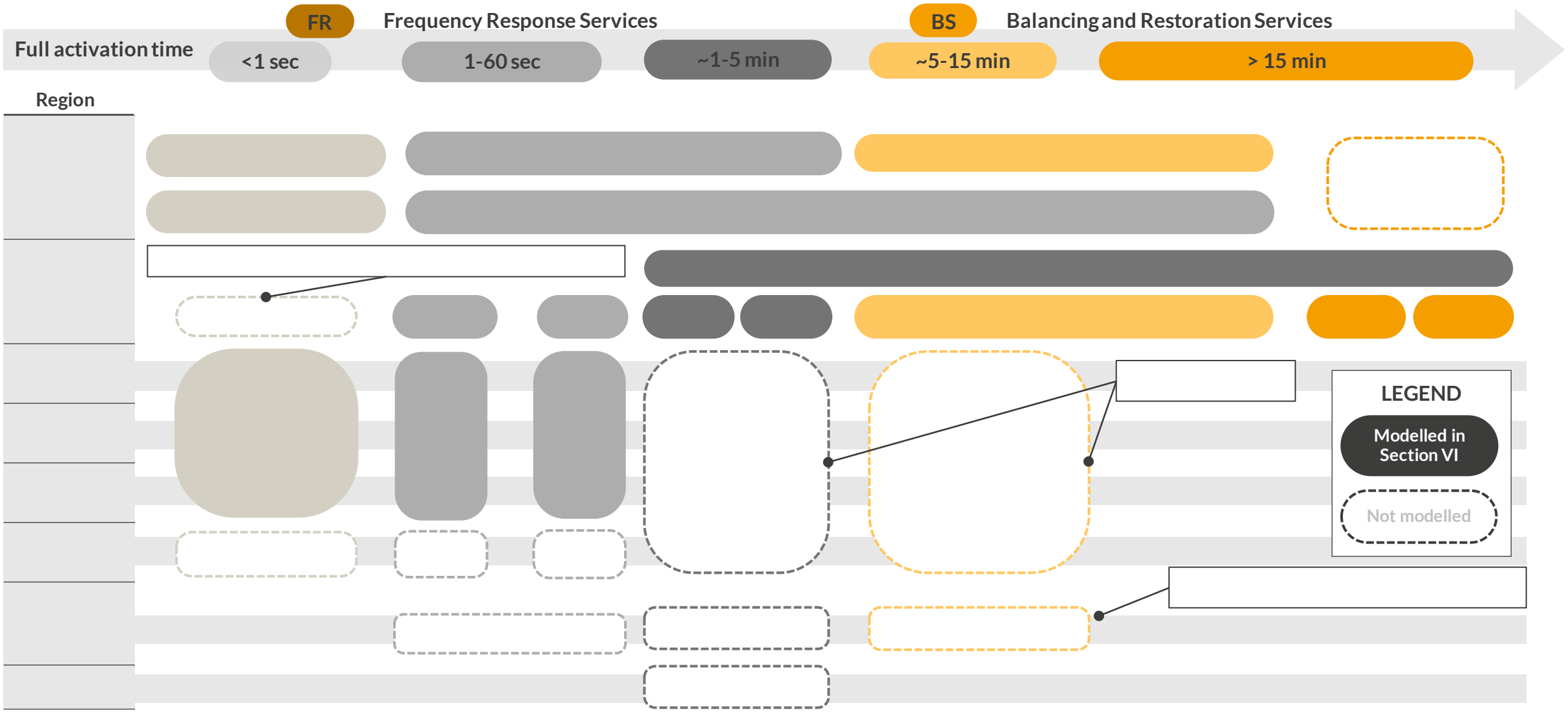

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Sources: Aurora Energy Research

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

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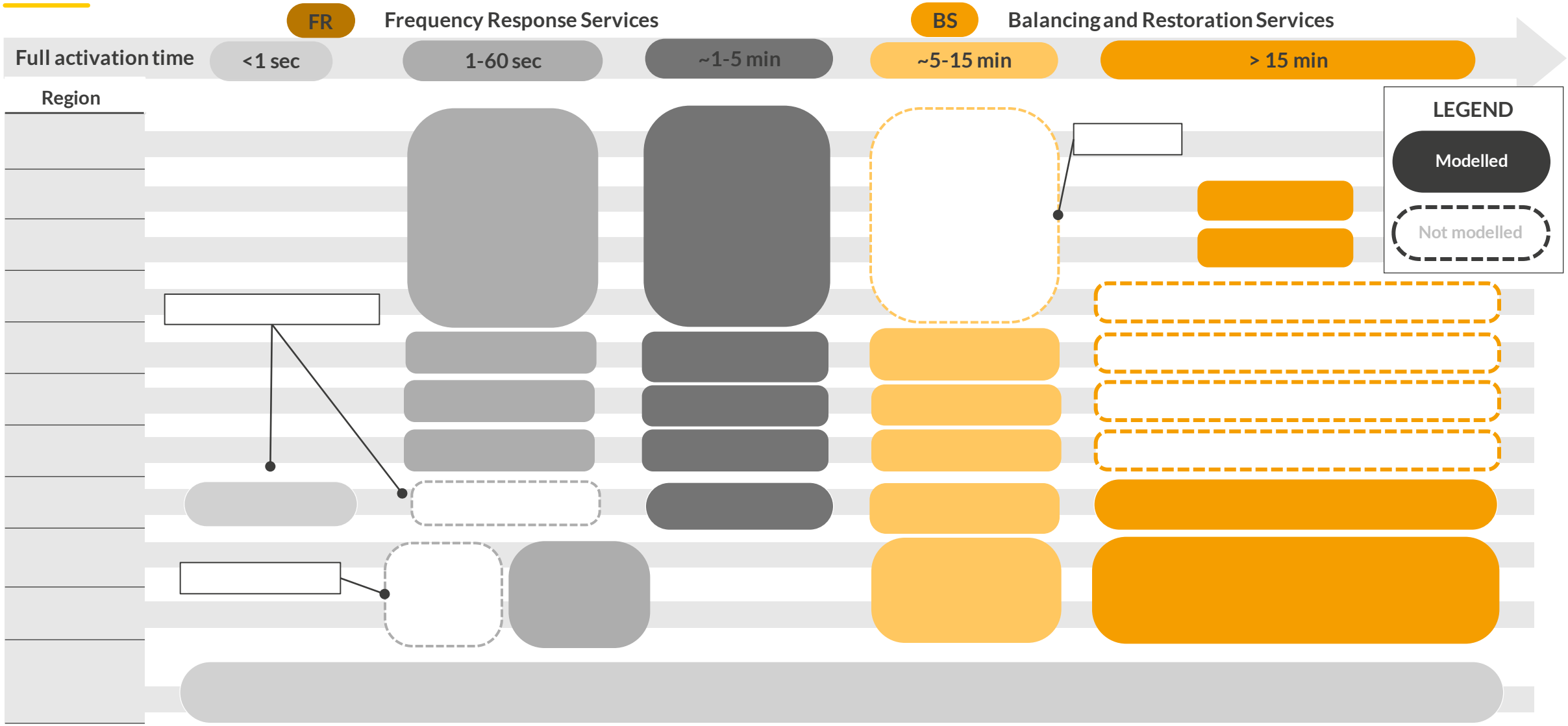

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Sources: Aurora Energy Research, Bundesnetzagentur, Elia, ENTSO-E, Regelleistung.net, TenneT

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

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

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The integration of electricity markets across the EU requires common rules across ancillary services

Platforms	Target Services	Implementation status	Implications
PICASSO **P**latform for the **I**nternational **C**oordination of **A**utomated Frequency Restoration and **S**table **S**ystem **O**peration	For automatic Frequency Restoration Reserves – **aFRR (energy)**, or secondary control		
MARI **M**anually **A**ctivated **R**eserves **I**nitiative	For manual Frequency Restoration Reserves – **mFRR**, or tertiary control		
TERRE **T**rans-**E**uropean **R**eplacement **R**eserves **E**xchange	For Replacement Reserves - **RR**, also part of ENTSO-E's tertiary control		
IN-IGCC **I**nternational **G**rid **C**ontrol **C**ooperation	To net energy imbalances between countries and avoid the simultaneous activation of Frequency Restoration Reserves (FRR) in opposite directions		

Sources: Aurora Energy Research, ENTSO-E

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

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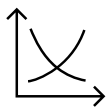
1 Status of PICASSO integration

2 Factors driving impacts of PICASSO integration on batteries



✓ Positive impact on battery outlook ▪ Minimal impact on battery outlook ? Uncertain impact on battery outlook

Sources: Aurora Energy Research, ENTSO-E

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Executive Summary

Revenue streams

[redacted] sees the most attractive revenue streams for battery storage, followed by [redacted] and [redacted]

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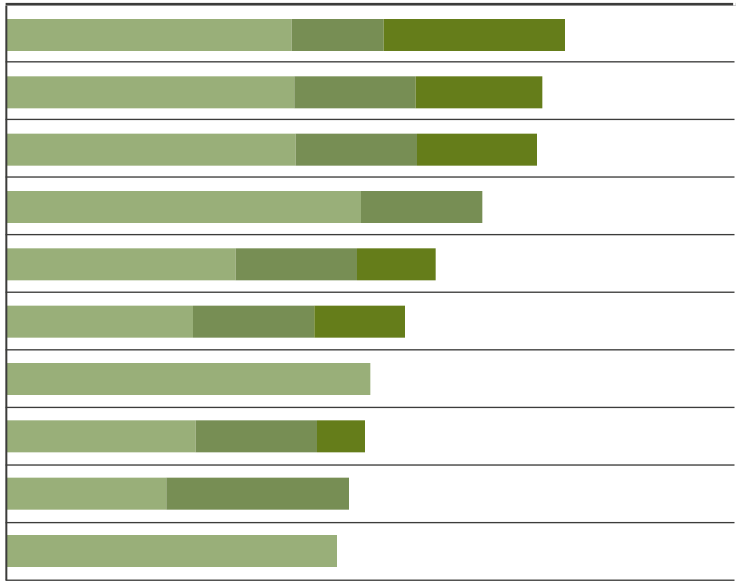
Revenue streams for battery storage

Countries are assessed in terms of their revenue streams for batteries between 2023-2030, based on two 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	*25%*	Assesses the risk of market saturation in frequency response and balancing services due to the deployment of other batteries
11 Capacity market revenues	*25%*	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

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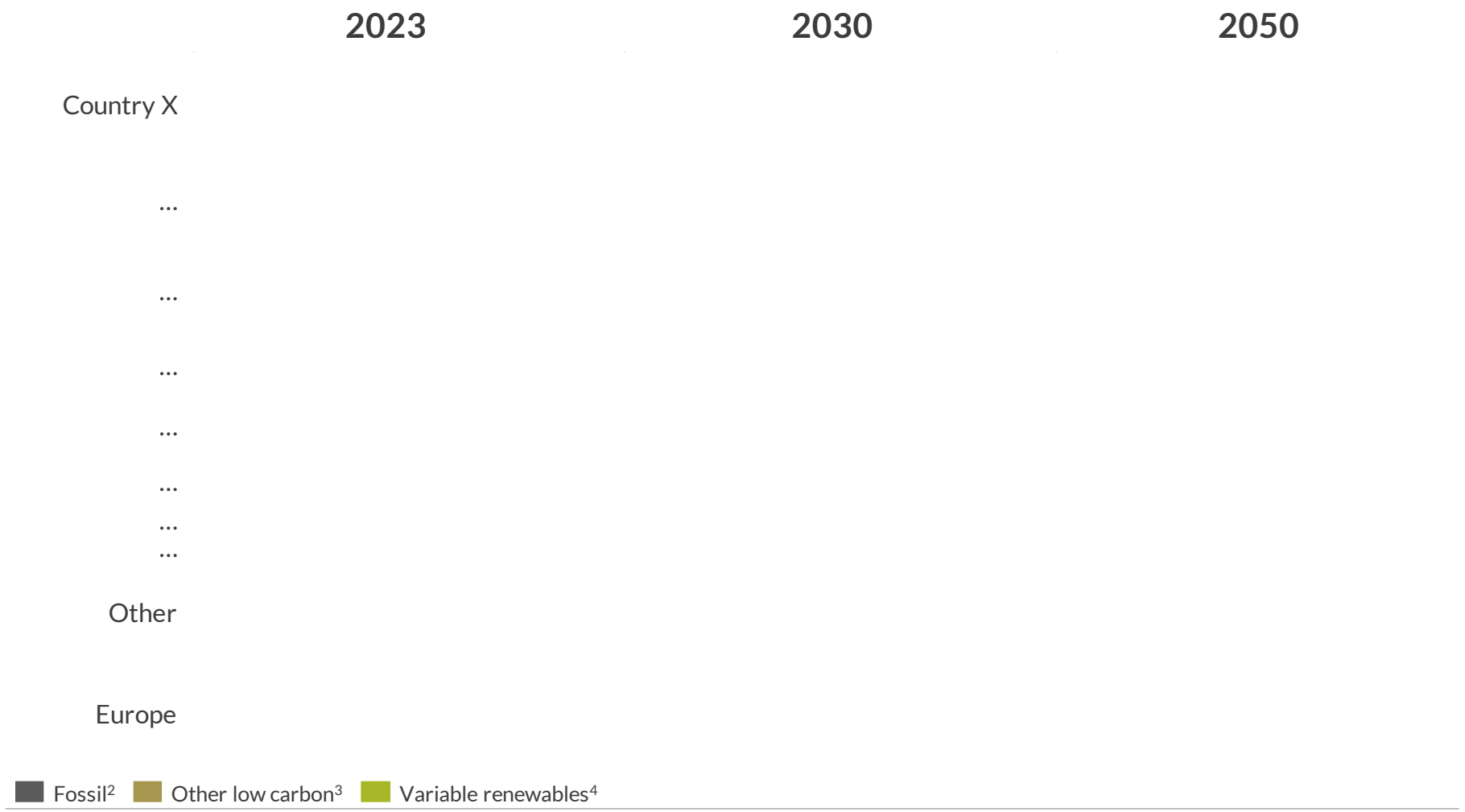
The share of wind and solar generation in Europe rises to [redacted]% by 2050, driving higher price volatility and system balancing needs

Share of total generation in Europe[1] (Aurora Central scenario)

%



Source: Aurora Energy Research

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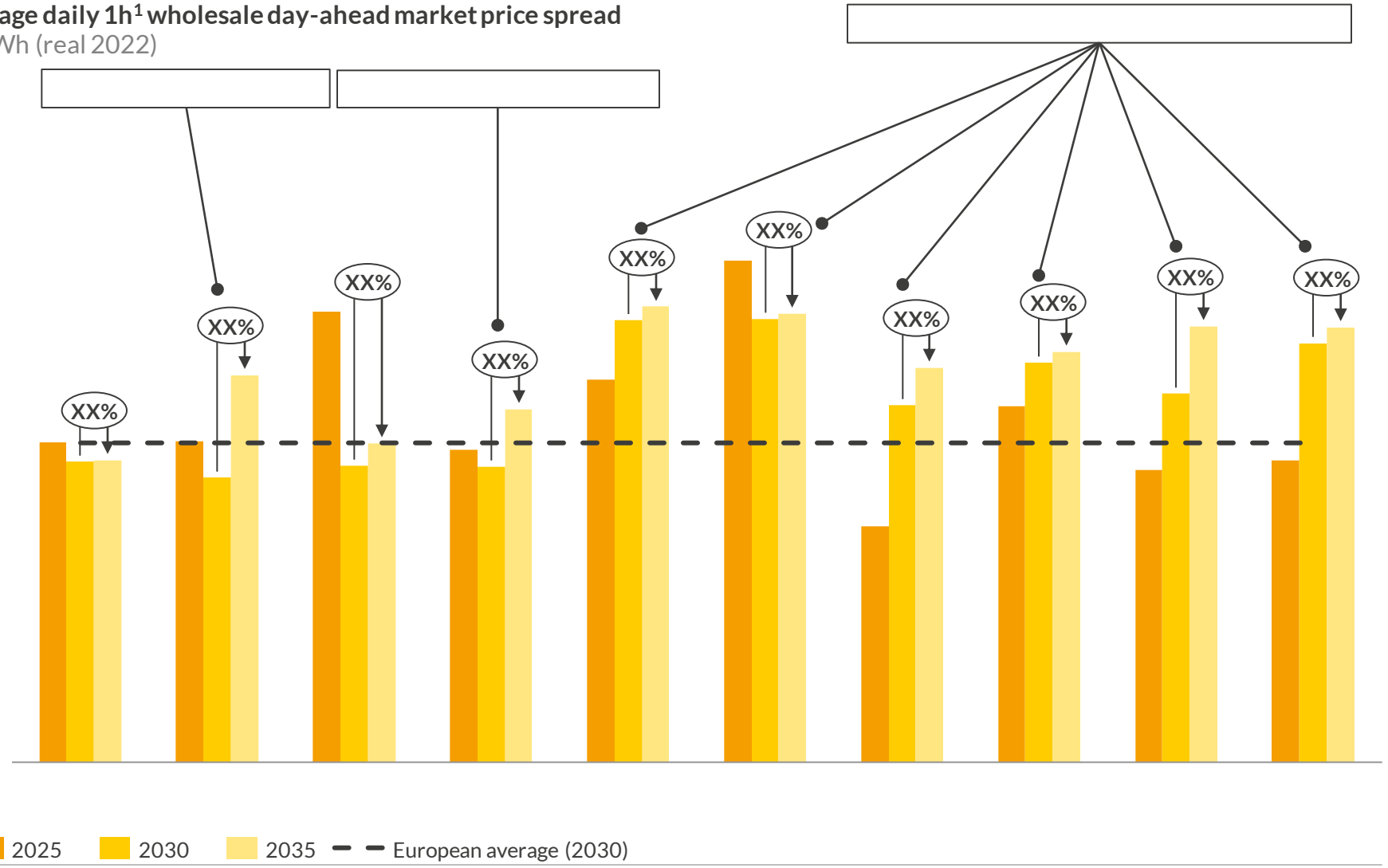
Wholesale price spreads rise in the 2030s across a few countries due to higher renewables penetration and rising commodity prices…

Average daily 1h[1] wholesale day-ahead market price spread
€/MWh (real 2022)



1) Yearly average of the daily spreads. The daily spreads are the difference between the average of the highest 1h and the lowest 1h for each day;

Source: Aurora Energy Research

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…while they decrease in other countries due to increased flexibility in the system from batteries, EVs and electrolysers

Source: Aurora Energy Research

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[redacted] shows highest demand for frequency response services, while [redacted] has the most batteries relative to market size

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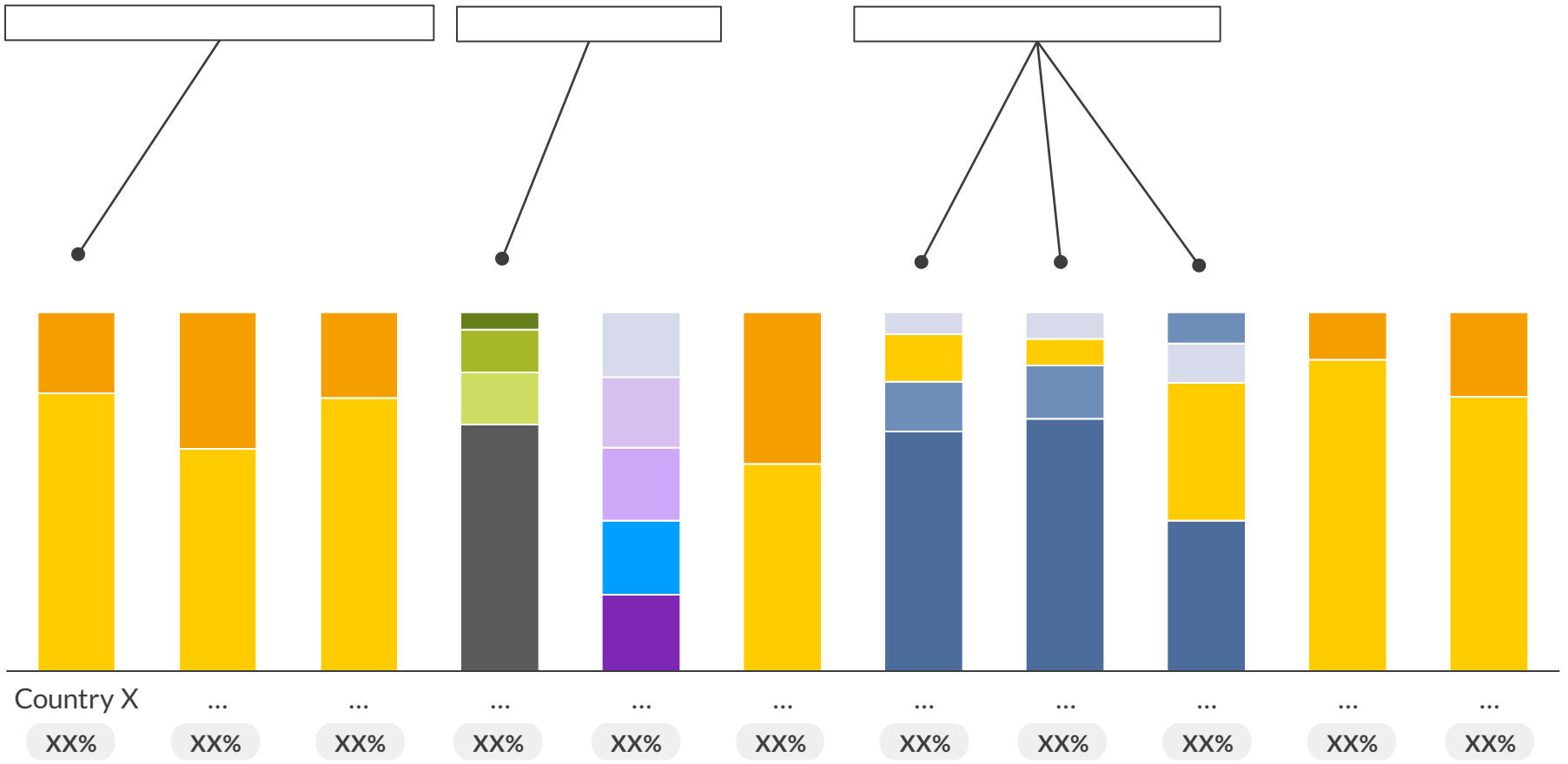
Annual volume procured by frequency response services

MW



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

Illustrative frequency response merit order
€/MW/h

Cost

Low battery capacity

Cost

High battery capacity

To gain access to this redacted information, get in touch with:

alex.hutcheson@auroraer.com

Battery Biogas CCGT Coal/Lignite Hydro Pump-Storage Hydro Run-of River Hydro Storage Dam OCGT

1) Both up and down regulation services are procured from the same bidder for each bidding period

Source: Aurora Energy Research

Aurora modelling methodology– Using Germany as an example (1/2)

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FCR bids are made based on reservation and opportunity costs in the Day Ahead market

AER-ES

- Long-term system overview
- Capacity and generation mix
- Wholesale prices
- Capacity market forecasts
- Granular asset performance

Asset-level FCR bids

Reservation costs → FCR bid

- Cost of maintaining a dispatch level that allows for a (symmetric) FCR bid
- Opportunity costs in the Day Ahead market

Four-hour, symmetric capacity bid placed

Merit order clearing

- Assembling of nationally placed bids
- Calculation of core shares and export limits
- Clearing of local merit orders
- Pay-as-clear price awarded to asset owners

Source: Aurora Energy Research

Aurora modelling methodology– Using Germany as an example (2/2)

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aFRR capacity and energy auctions are based on opportunity and reservation costs, are uncoupled and treated as such in our modelling

AER-ES

- Long-term system overview
- Capacity and generation mix
- Wholesale prices
- Capacity market forecasts
- Granular asset performance

aFRR capacity bids

Reservation costs → Capacity bids

- Upwards and downwards capacity bids carry different reservation costs
- An upwards bid requires capacity 'on hold'
- For a downwards bid, an asset owner must be producing

Capacity bids placed

Clearing of local merit orders

Pay-as-bid price awarded to asset owners

aFRR energy bids[1]

Opportunity costs → Energy bids

- Asset owners base their energy bids based on their Day Ahead positions
- These decisions are made independently of the aFRR capacity auction, which clears earlier

Energy bids placed

Clearing of local merit orders

Pay-as-clear price awarded to asset owners

1) This analysis incorporates Net Transfer Capacity (NTC) flows in the calculation of PICASSO bids.

Source: Aurora Energy Research

The increasing penetration of flexible assets and the decrease in hydro power revenues pull down frequency response services prices (1/4)

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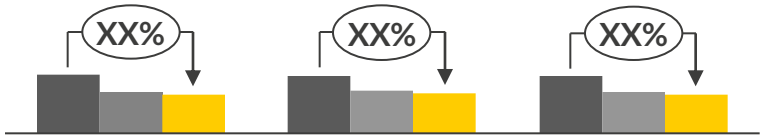
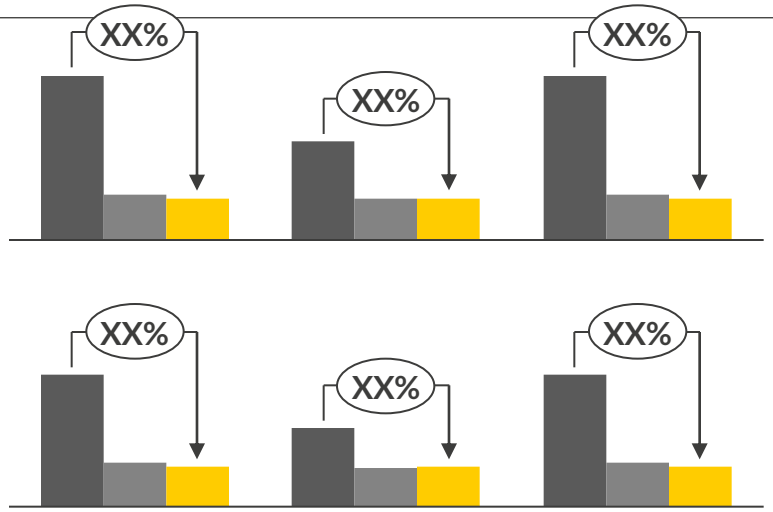
Capacity reservation price of selected services, €/MW/h (real 2022)

Comments

Country X



Country Y



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Source: Aurora Energy Research

[redacted]'s saturated frequency response market causes a stable prices while sees an increasing trend due to higher demand for reserve services (2/4)

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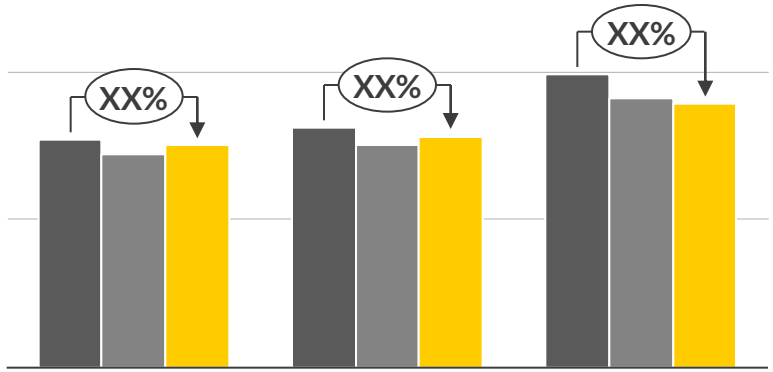
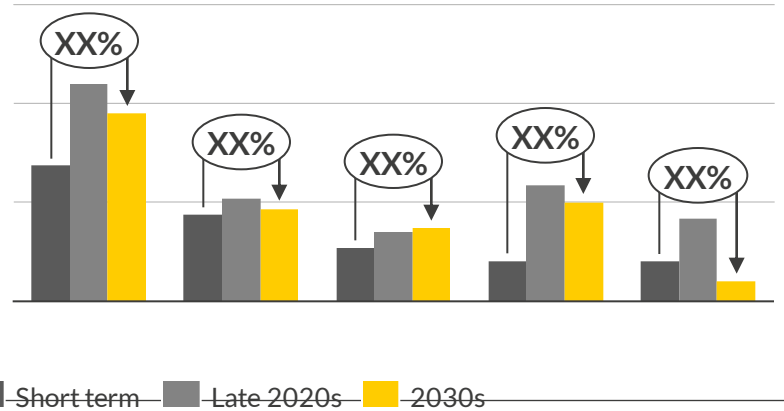
	Capacity reservation price of selected services	Comments
Country Z		
...		This is a redacted sample of the European Battery Market Attractiveness Report. If you are interested in the full report, contact Alex Hutcheson (alex.hutcheson@auroraer.com)

Short term Late 2020s 2030s

Source: Aurora Energy Research

Retirement of thermal assets and battery deployment steadily reduce frequency service costs in [redacted] (3/4)

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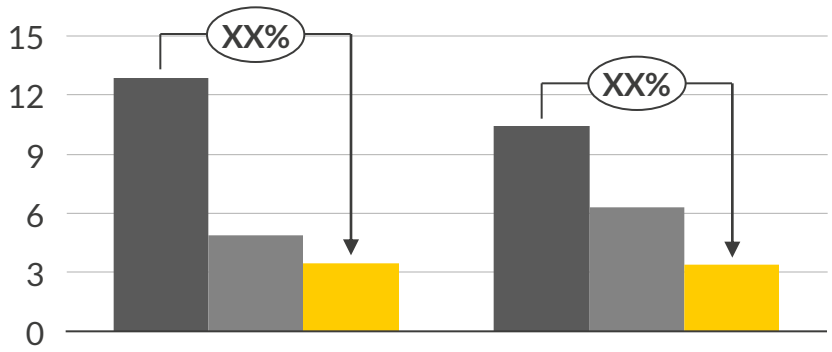
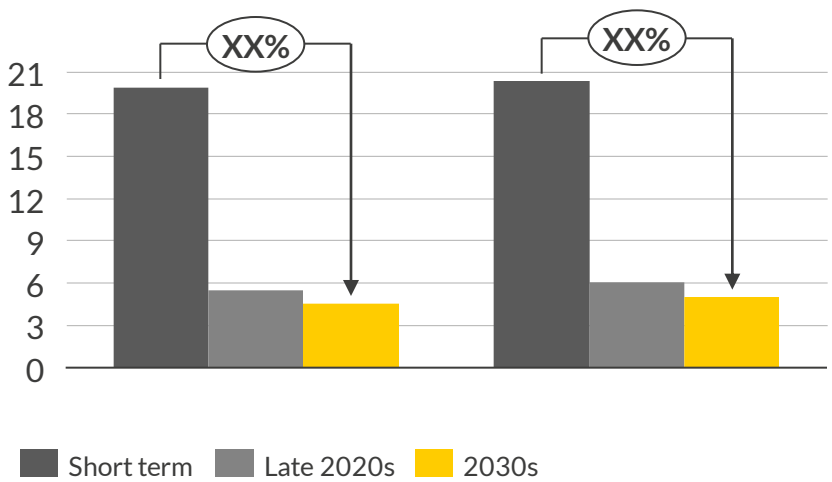
Capacity reservation price of selected services, €/MW/h (real 2022)

Comments

...



...



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Source: Aurora Energy Research

Increased battery participation and regulatory shifts drive down frequency service prices in [redacted] (4/4)

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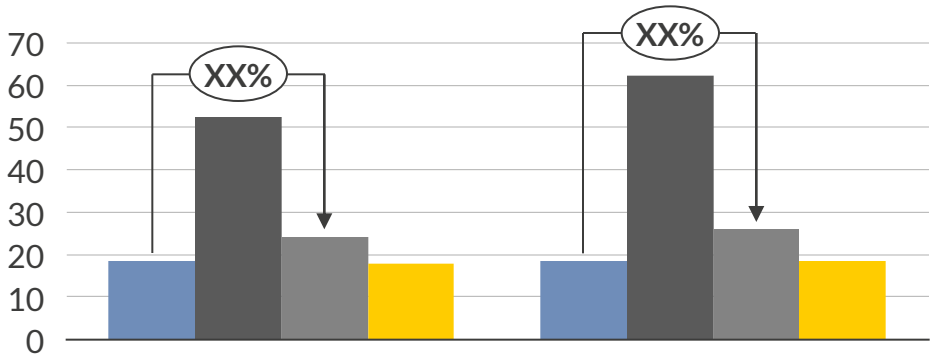
...

Capacity reservation price of selected services, €/MW/h (real 2022)



Comments

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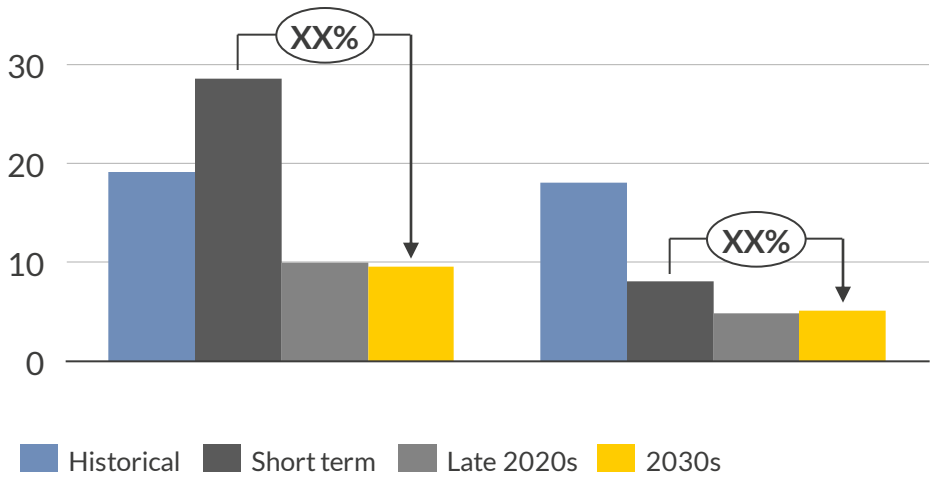

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Source: Aurora Energy Research

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Balancing service prices rose to unprecedented levels over the past couple of years driven by high commodity price volatility in 2022

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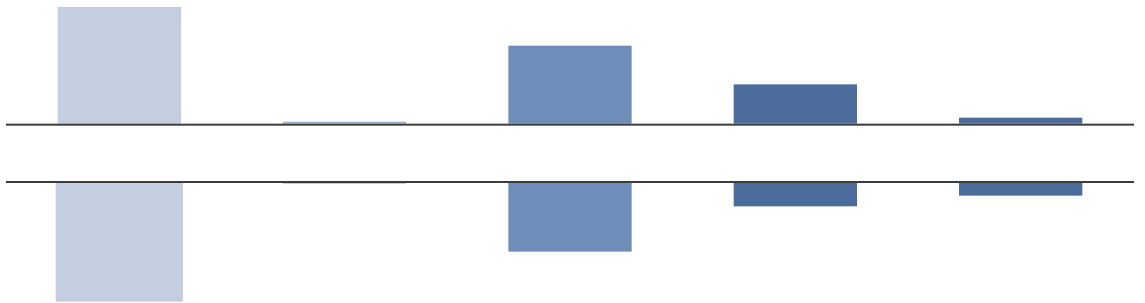
Market description

Size relative to wholesale market[1], % xx%

Region	Balancing and Restoration Services

Total accepted volumes Up/Down services in 2022
GWh



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

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

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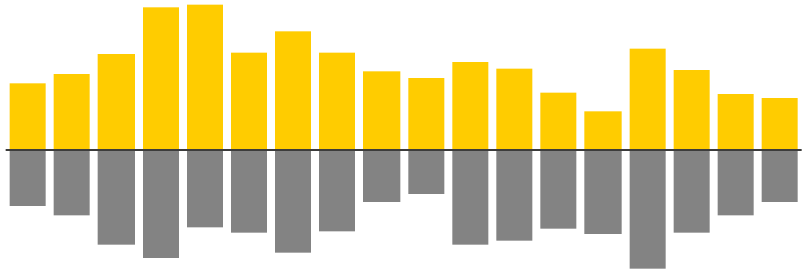
Net imbalance volume duration curve
Half-hourly, GWh

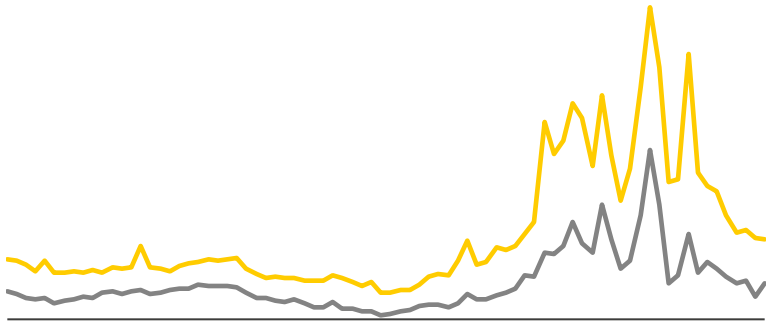
Historical balancing volumes
TWh

Indicative country example



Historical average monthly system prices[2]
£/MWh

Indicative country example



2023 2030 2040 2050 2060

Percentage of time in year

Short Long Accepted offers Accepted bids

1) Quarter 3 of 2023 includes July and August but no data from September. 2) Single Imbalance Price. The imbalance price is the price applied to all parties out of balance, scaled by the magnitude of deviation from contracted volumes.

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)

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

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1) Represents the average imbalance price when the system is short

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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Source: Aurora Energy Research

Battery business models will rely more on revenue stacking as frequency services across Europe face increased saturation risk

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Summary of saturation risks for grid-scale batteries[1]

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)

Will take longer to saturate (> 3) | Will saturate within the near term (1-3 years) | Already saturated | Not relevant for batteries

Source: Aurora Energy Research

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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?

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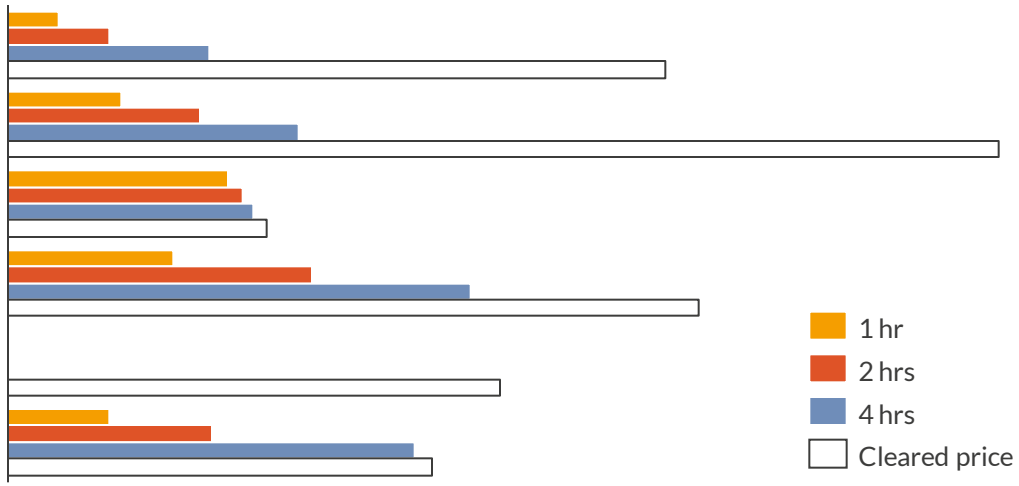
Source: Aurora Energy Research

Capacity Markets support over [redacted] GW of batteries across Europe, although revenues vary due to de-rating factors and clearing prices

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 2022)



- Over [redacted] GW of batteries have secured contracts in capacity markets (CM) in [redacted] countries, of which [redacted] GW are located in [redacted].
- In [redacted], batteries dominated the [redacted] auction, with over [redacted] GW of batteries securing CM contracts, of which [redacted] hr batteries comprise [redacted] MW of nameplate capacity.
- Auctions are generally held annually, with delivery for new build assets typically 4 years after the conclusion of the auction.
- In [redacted], the [redacted] auction for delivery in [redacted] awarded over [redacted] 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.
- [redacted] Capacity Market requires [redacted] hours of continuous generation, so batteries with duration under [redacted] hours must compete with reduced capacity ([redacted]).
- Due to its [redacted] system, CM prices awarded to batteries in [redacted] are not known
- Capacity market revenues generally only make a relatively small contribution to battery business cases

Source: Aurora Energy Research

Contracted revenues from Capacity Markets enhances battery bankability, but may restrict participation in other markets (1/2)

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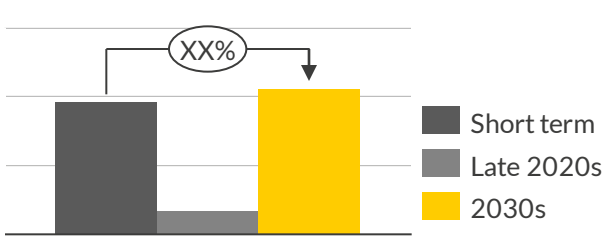
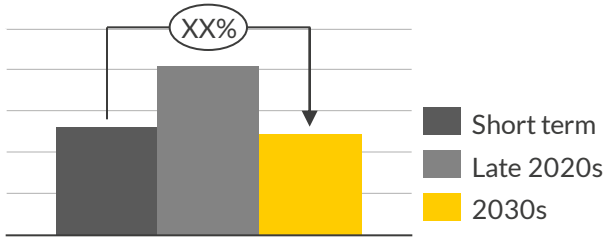
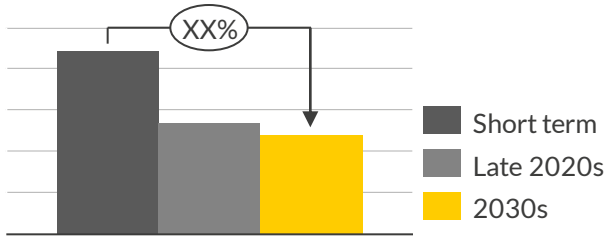
	Country X	Country Y	...
Clearing price €/kW (real 2022)			
CM contract tenor[1]			
Price caps or constraints			
Market overview & Anticipated developments	This is a redacted sample of the European Battery Market Attractiveness Report. If you are interested in the full report, contact Alex Hutcheson (alex.hutcheson@auroraer.com)		

Source: Aurora Energy Research

Contracted revenues from capacity markets enhances battery bankability, but may restrict participation in other markets (2/2)

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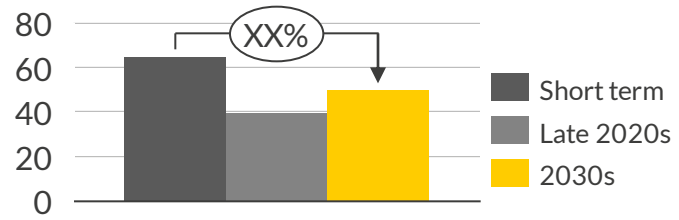
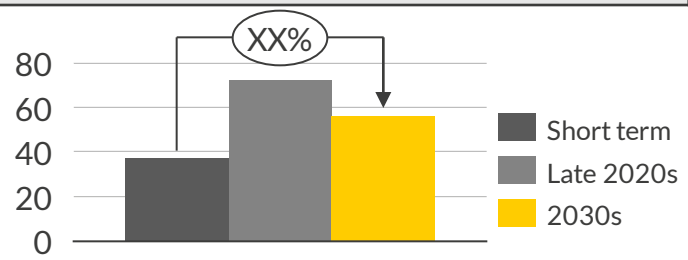
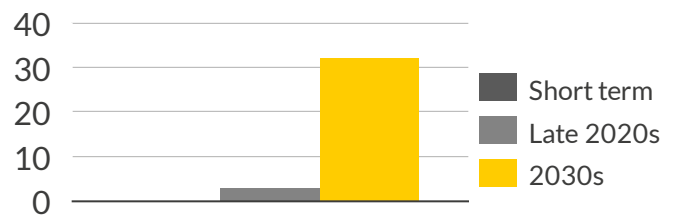
	Country X	Country Y	…
Clearing price €/kW (real 2022)			
CM contract tenor[1]			
Price caps or constraints			
Market overview & Anticipated developments	This is a redacted sample of the European Battery Market Attractiveness Report. If you are interested in the full report, contact Alex Hutcheson (alex.hutcheson@auroraer.com)		

Source: Aurora Energy Research

Agenda

Want to see the whole report?
Curious about Aurora's offerings and services?
Looking for more information?

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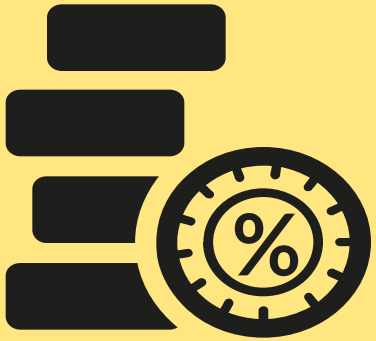
Executive Summary

Project economics



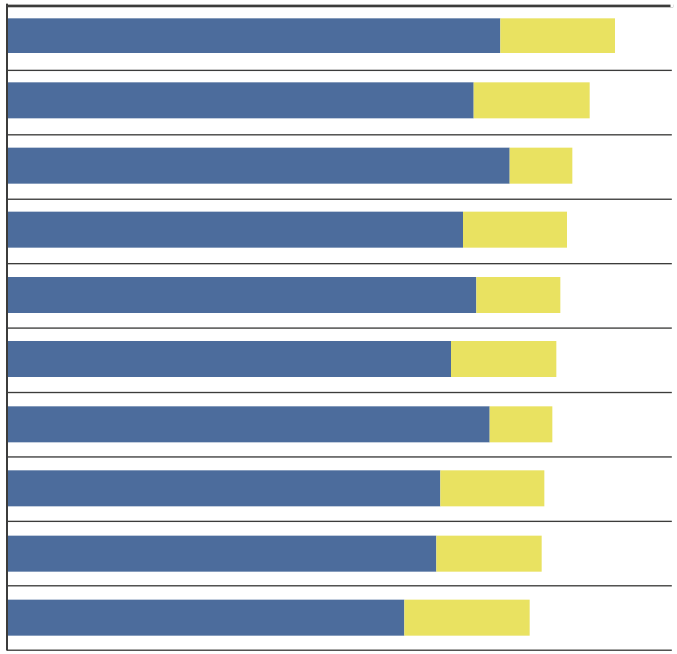
[redacted] sees the most attractive project economics for battery storage, followed by [redacted] and [redacted]

Project economics

Countries are assessed in terms of their economic outlook for batteries, reflected through indicative fully merchant IRRs and potential for colocation, with scores assigned between 0-10 where the maximum IRR = 10 and minimum = 0.

Metric	Weighting	Rationale
12 Indicative fully merchant IRR for project starting in 2027[1]	80%	Captures the commercial viability of new build projects for final investment decisions in 2 - 3 years' time based on fully merchant business models
13 Enabling environment for co-location	20%	Accounts for access to other revenue streams and cost savings from cable pooling

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



Top markets

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

Source: Aurora Energy Research

The gross margin stack is formed largely by capacity-based ancillary services in the [redacted], but energy arbitrage is prevalent elsewhere

Average composition of gross margin stack
% of 2027 – 2041

1 hr battery

2 hr battery

Energy arbitrage (Wholesale Market + Ancillary Services + Balancing Services)
Capacity payments for ancillary services
Capacity Market Payments
Other ancillary markets[6]

(*)each bar indicates individual countries gross margins.

Source: Aurora Energy Research

Detailed country data available in Aurora's Flexibility Energy Market subscriptions

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The need for longer duration storage increases with rising renewables penetration; 4-hour batteries benefit most from arbitrage revenues

Average composition of gross margin stack
% of 2027-2041

4 hr battery

Energy arbitrage (Wholesale Market + Ancillary Services + Balancing Services)
Capacity payments for ancillary services
Capacity Market Payments
Other ancillary markets[4]

(*)each bar indicates individual countries gross margins.

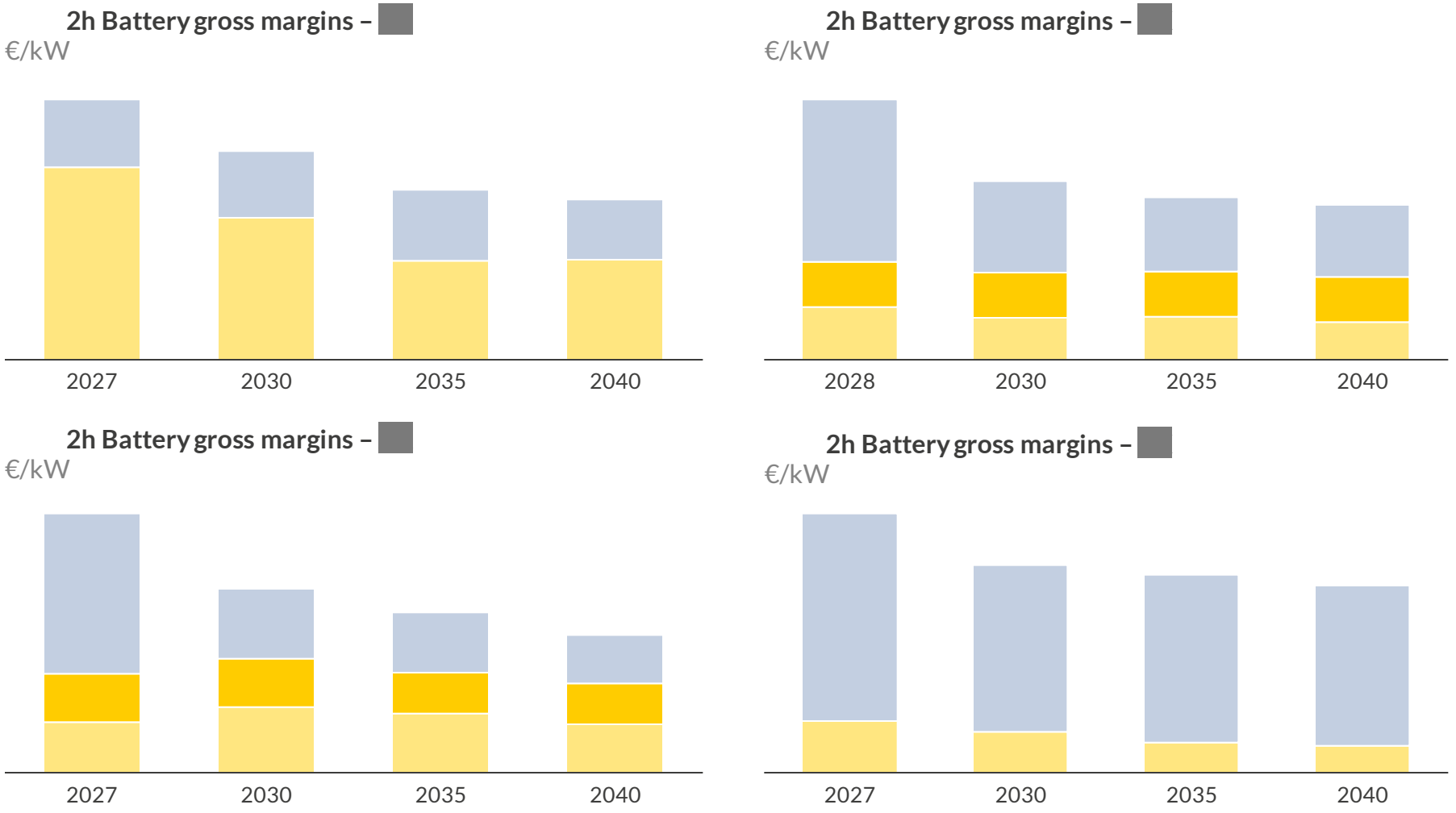
Source: Aurora Energy Research

Detailed country data available in Aurora's Flexibility Energy Market subscriptions

Battery gross margins
Central scenario

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)

Gross margins decrease over time as batteries degrade, and the composition of gross margins changes in diverse ways



(*)each graph indicates individual countries gross margins.

Detailed country data available in Aurora's Flexibility Energy Market subscriptions

Source: Aurora Energy Research

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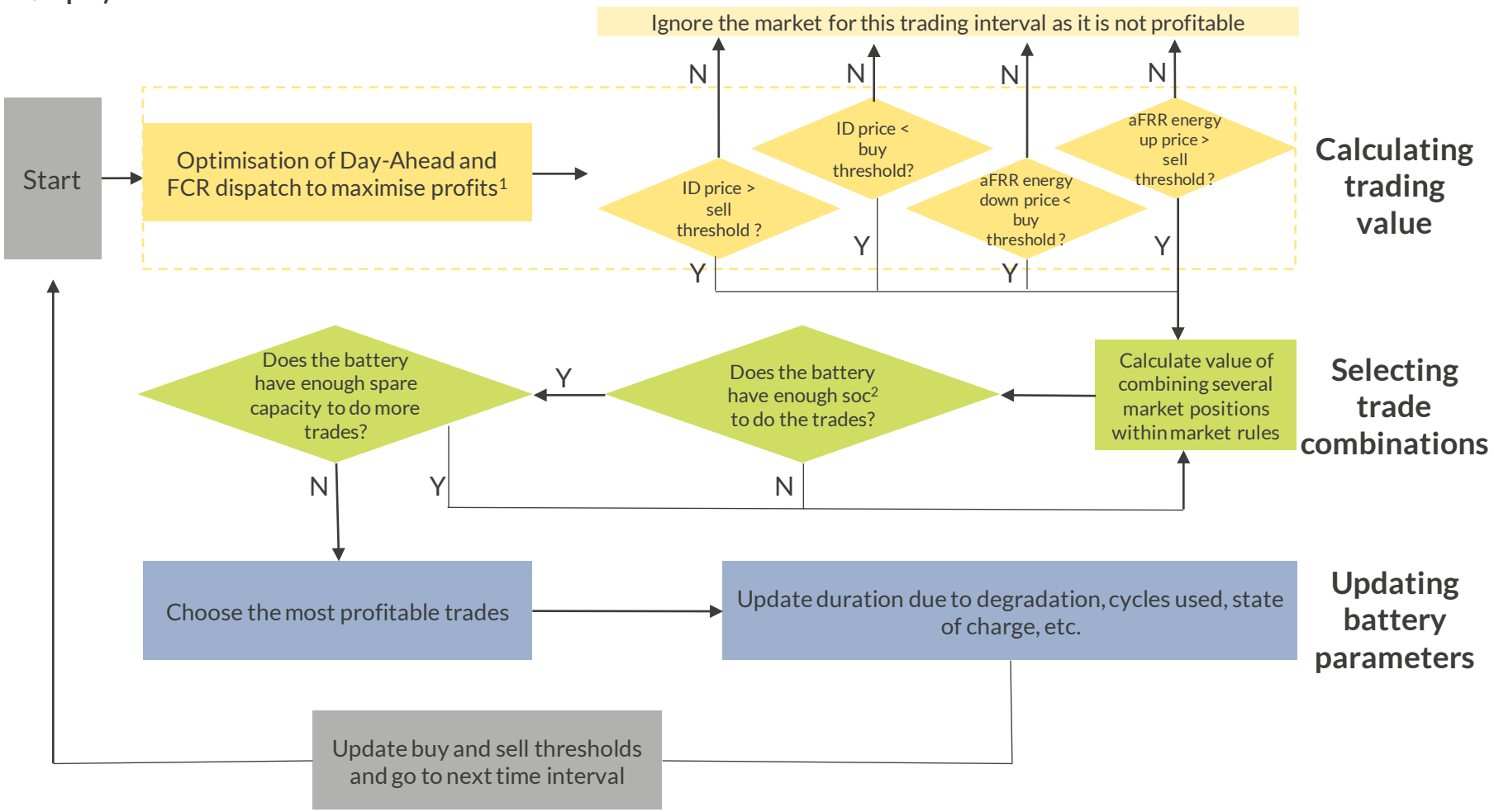
This is a redacted sample of the European Battery Market Attractiveness Report. If you are interested in the full report, contact Alex Hutcheson (alex.hutcheson@auroraer.com)

Modelling approach: Based on real market mechanisms, our model dispatches according to the following logic

Overview of trading heuristic (DEU example):



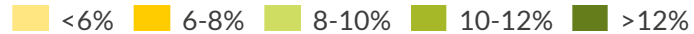
- The asset has foresight into the Day-Ahead (DA) and FCR prices for 1 day and uses that to determine prices to charge and discharge at. It has only limited foresight into the Intraday (ID) and no foresight into aFRR energy markets
- **Sell threshold** and **buy threshold** represent the lowest and highest price at which the battery is willing to sell and buy power. As the battery has imperfect foresight, the thresholds are determined based on the prices the battery has observed in DA and FCR, and partly Intraday[3]
- When calculating the value of combining market positions, the model iterates over all possible combinations of the profitable trades within market rules and limits

1) Given an option value parameter for how much capacity the battery wants to reserve for ID/aFRR; 2) State of charge; 3) Foresight on Intraday prices is limited to next committed DA trade. No foresight on aFRR energy

Source: Aurora Energy Research

High capacity-based ancillary market revenues drives 1h batteries business cases …

Project IRR ranges for standard projects (2027 as entry year – unlevered)[1]
%, pre-tax, Central scenario



Region	Project IRR[2]	Comments
	1h 2h 4h	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)
	1h 2h 4h	
	1h 2h 4h	
	1h 2h 4h	
	1h 2h 4h	

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. Ranges are inclusive of lower bound.

Source: Aurora Energy Research

… but with increased market saturation over time, energy arbitrage favours 2h and 4h durations (1/2)

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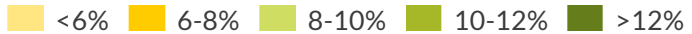
Project IRR ranges for standard projects (2027 as entry year – unlevered)[1]
%, pre-tax, Central scenario



Region	Project IRR	Comments
	1h 2h 4h	
	1h 2h 4h	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)
	1h 2h 4h	
	1h 2h 4h	
	1h 2h 4h	

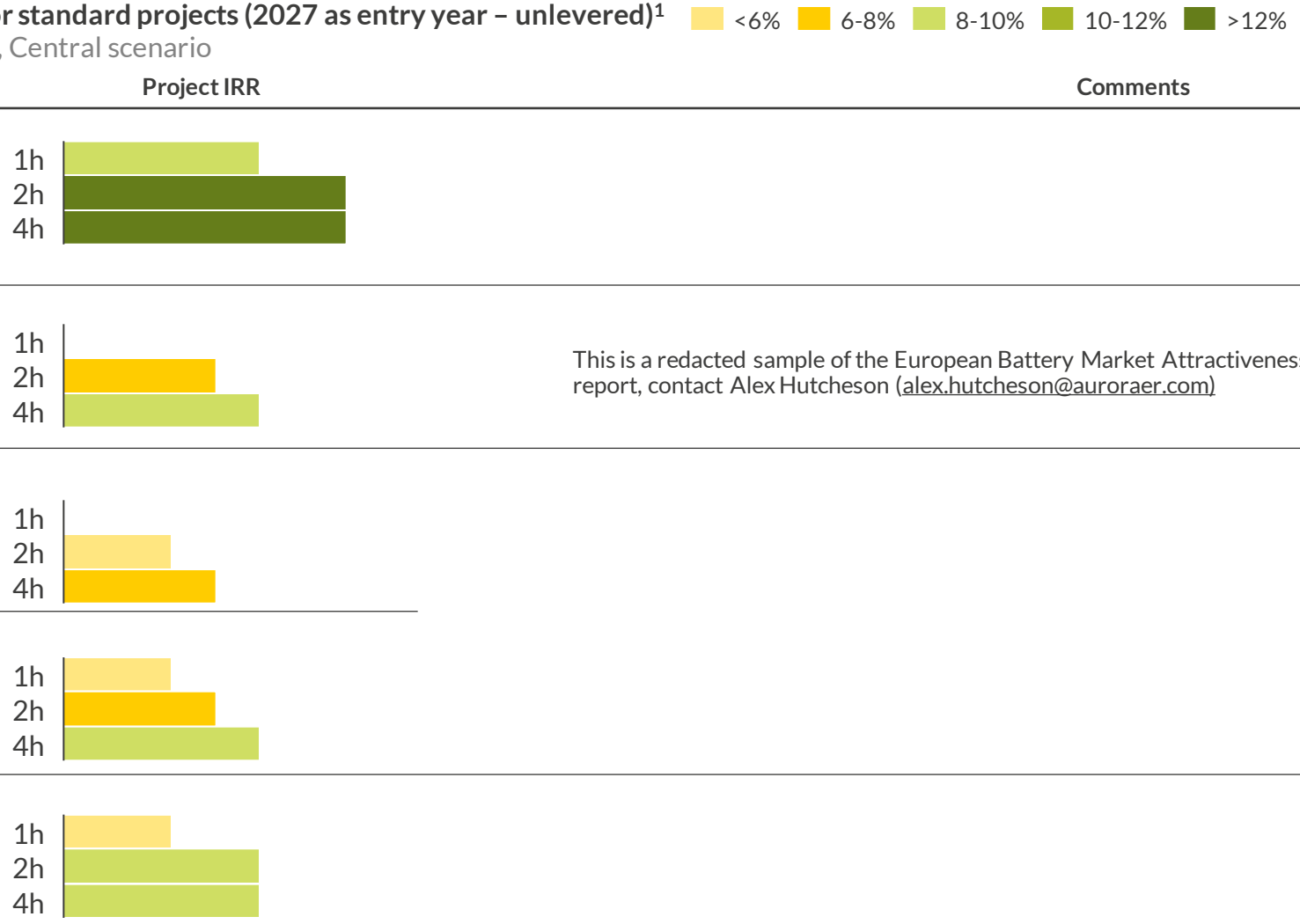
1) Standard case represents standalone business cases for assets optimising among energy arbitrage, capacity-based ancillary services, and capacity markets cashflow. IRRs are based on Aurora's internal cost assumptions. Ranges are inclusive of lower bound.

Source: Aurora Energy Research

… but with increased market saturation over time, energy arbitrage favours 2h and 4h durations (2/2)

AURORA

Project IRR ranges for standard projects (2027 as entry year – unlevered)[1]
%, pre-tax, unlevered, Central scenario



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. Ranges are inclusive of lower bound.

Source: Aurora Energy Research

In the High scenario, batteries have a better business case due to stronger energy trading opportunities …

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Economics for new-build 2-hour, 1.5 cycle/day batteries in 2027 in [redacted]
Present value, £/kW (real 2022)

To gain access to this redacted information, get in touch with:

alex.hutcheson@auroraer.com

Energy Trading | Dynamic Containment | Capacity Market | Other

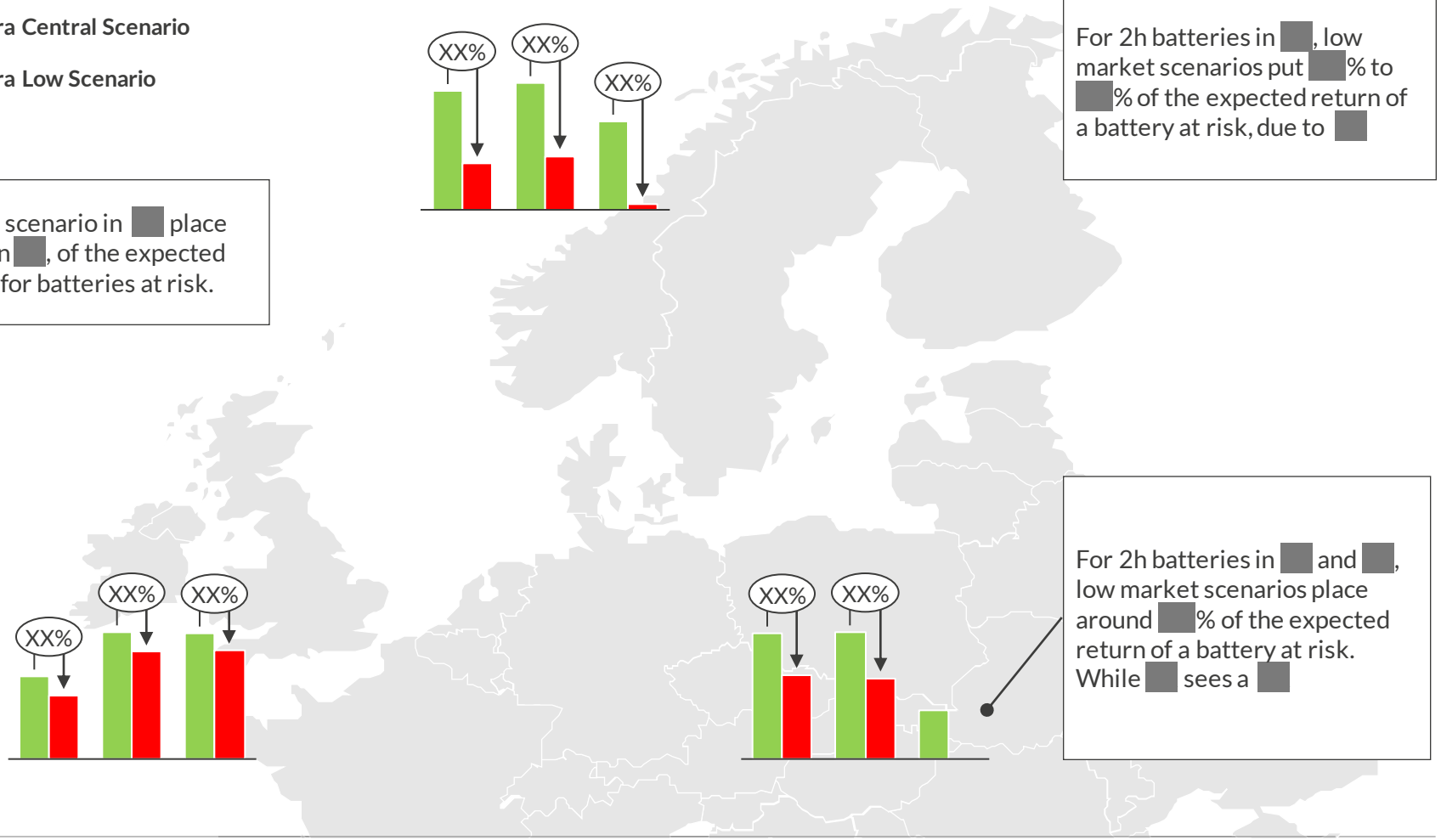
Source: Aurora Energy Research

… While in Low Scenarios, battery investments have a different degree of exposure

Expected profitability for batteries with COD 2027
IRR % (pre-tax, real)

- Aurora Central Scenario
- Aurora Low Scenario

The low scenario in [redacted] place between [redacted], of the expected returns for batteries at risk.



For 2h batteries in [redacted], low market scenarios put [redacted]% to [redacted]% of the expected return of a battery at risk, due to [redacted]

For 2h batteries in [redacted] and [redacted], low market scenarios place around [redacted]% of the expected return of a battery at risk. While [redacted] sees a [redacted]

.

Sources: Aurora Energy Research

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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)

To prepare for uncertainties in the markets, developers can apply different strategies with significant upside scenarios

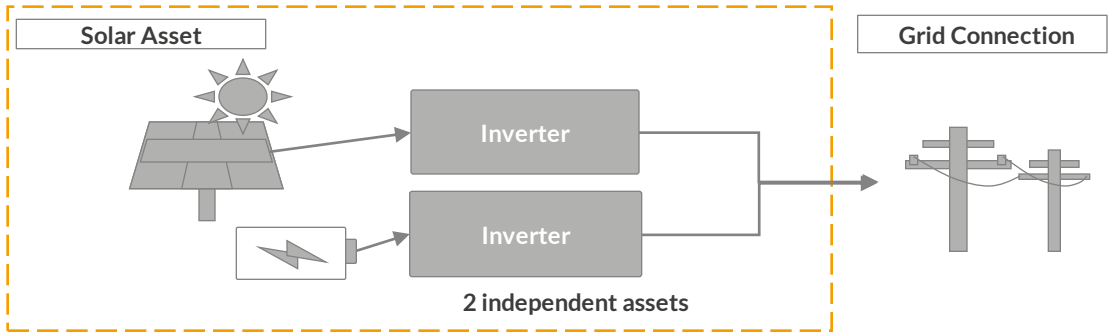
1 Managing Degradation and Revenue Resets

- Oversize
- Reduce
- Augment
- Repower
  Deep Dive

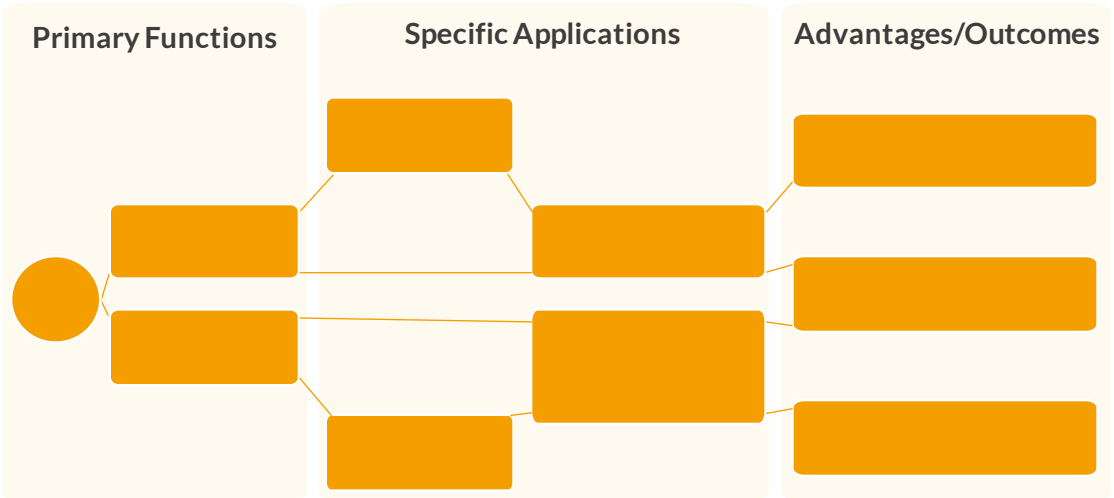
2 Co-located Solar and Battery[1]

Deep Dive

AC Schematic description AC connected co-located solar and battery project

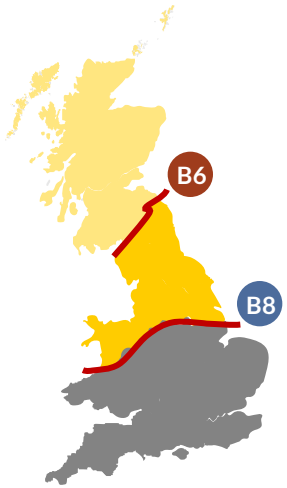


3 AI supported Intraday trading



4 Grid location[2] & Congestion revenues

Illustrative



Source: Aurora Energy Research

1 Multiple strategies are viable for battery storage, with trade-offs between near-term cost and long-term technical complexity

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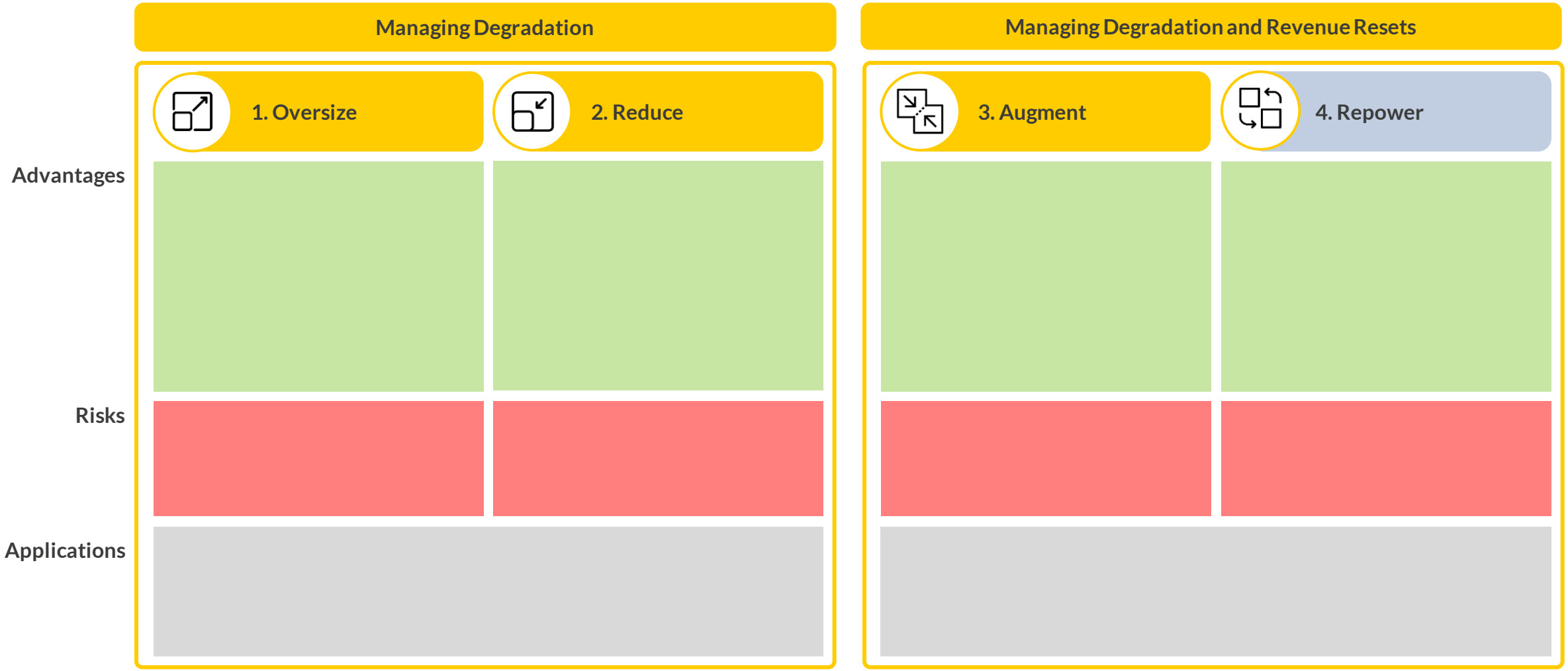
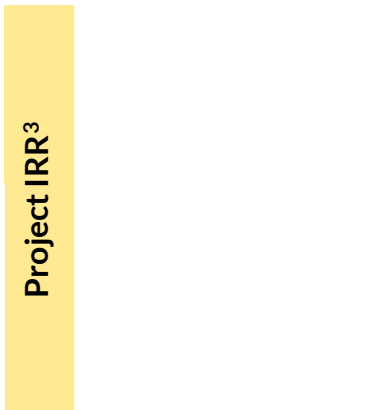


Source: Aurora Energy Research

1 Repowering extends the battery lifetime allowing them to capture higher revenues, and potentially increasing profitability

Economics for a repowering new-build 1-hour 2 cycle/day battery in [redacted] in 2027

€/kW, real 2022



Standard Repowering

Source: Aurora Energy Research

2 Batteries co-located with AC-coupled solar PV can have significantly higher IRR than standalone

Project Internal Rate of Return[1] (real and unlevered, Battery COD 2027)
%

Standalone battery, no repowering
Standalone battery, repowering
Battery Co-located solar PV (AC-coupled), repowering

Source: Aurora Energy Research

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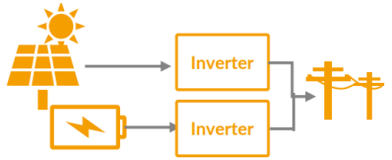
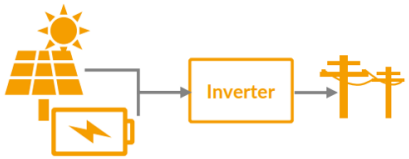
2 Colocation of batteries with renewables could increase battery IRRs through cost savings and project optimisation





Factor	Description	AC-coupled	DC-coupled

To gain access to this redacted information, get in touch with:

alex.hutcheson@auroraer.com

Full benefit | Partial benefit | No benefit | Negative impact

1) Inverters are undersized compared to peak solar capacity, since the actual output of solar assets is usually much lower than the peak, and thus little energy is lost by reducing costs of inverter by under sizing. Since recently, to participate in the SDE++ solar assets are obliged to undersized their inverter by 50%.

Source: Aurora Energy Research

2 Aurora's rating of four key categories is used to enable environment for co-location projects

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Regulatory Framework	1	No specific policy, strategies nor targets supporting storage or co-location
	2	Regulatory support for storage or co-location with unclear or little impact
	3	Targets and policies favoring storage and co-located projects
Grid Integration	1	Limited grid availability, high connection (upfront) costs, restrictions to hybrid projects
	2	Average connection times and costs for grid connection
	3	Priority for connecting co-located projects and/or grid fees exemptions , vast grid availability
Subsidies and Incentives	1	No subsidies available for storage or co-location
	2	Potential incentives favoring storage and co-located projects with unclear or little impact
	3	Current or future incentives (e.g. auctions) favoring co-located projects and/or storage
Market access and revenue potential	1	Limited or unlear market access for storage or co-located assets
	2	Several markets available for storage and co-located assets with restrictions on participation or low revenues
	3	Multiple diverse revenue streams for storage and co-located assets with no restrictions, long-duration contracts available (i.e. CM)

Enabling environment for Co-location

Traffic Light Score Legend

4-6	Not attractive
7-9	Moderately attractive
10-12	Currently attractive

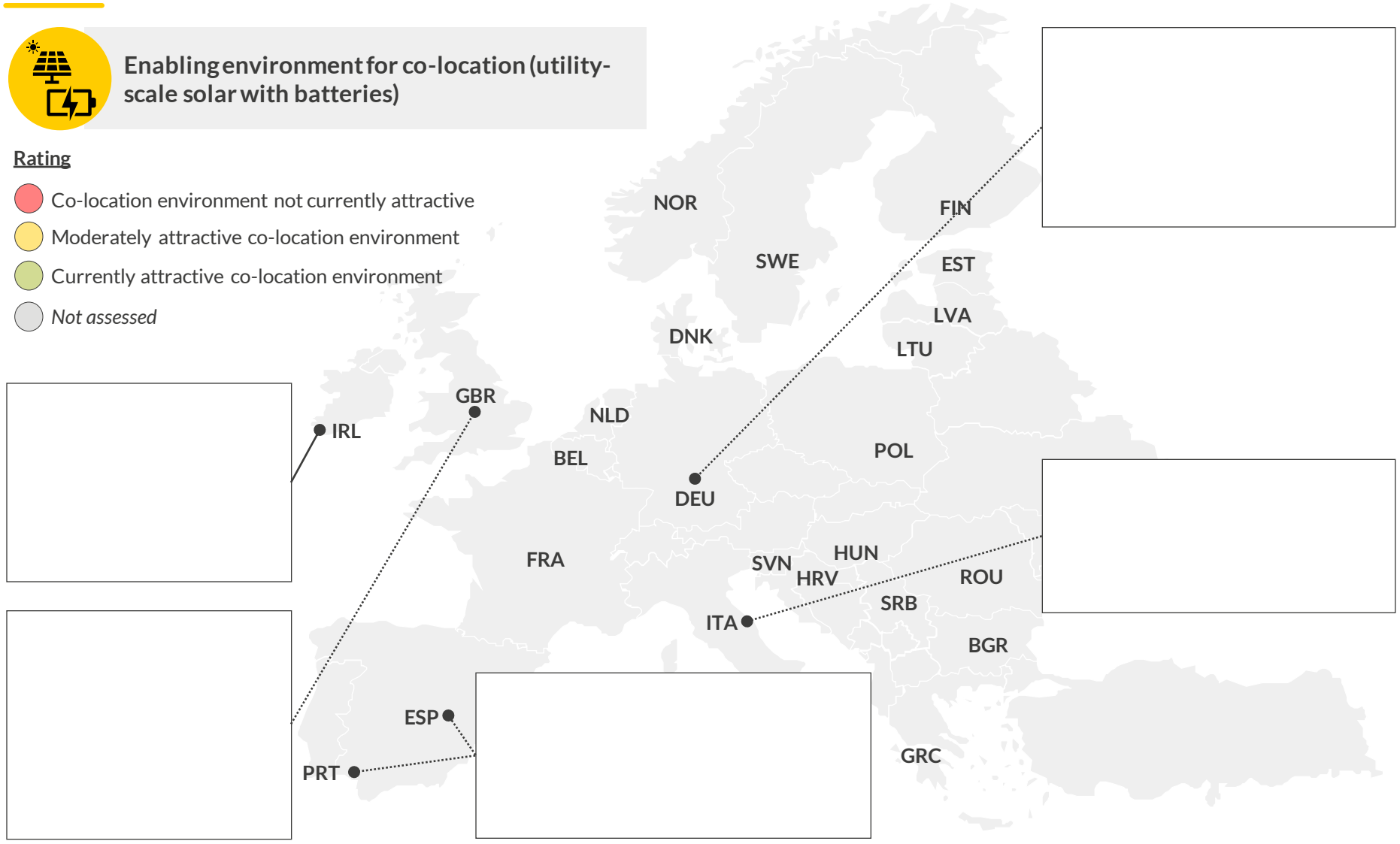
.

2 Favourable policy environment has enabled co-located projects in markets such as [redacted], [redacted], [redacted] and [redacted]

Enabling environment for co-location (utility-scale solar with batteries)

Rating

- Co-location environment not currently attractive
- Moderately attractive co-location environment
- Currently attractive co-location environment
- *Not assessed*



Source: Aurora Energy Research

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Unique, proprietary, in-house modelling capabilities underpin Aurora's superior analysis

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4 Integrated Models

Hydrogen (AER-HY)

Carbon (AER-ETS)

Power markets (AER-ES)

Global Commodities & Gas (AER-GLO/GAS)

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
- 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

Glossary

A Key terms

- **Ancillary services:** functions that help grid operators maintain a reliable electricity system
- **Battery duration:** ratio of MWh to MW for the asset, in hours
- **Battery degradation**: decrease in storage capacity and depth of discharge of batteries with time and use
- **Gross margins:** net trading profit from buying and selling power in the wholesale market and ancillary services only; does not include any fixed charges, additional variable costs or benefits that may apply or other cashflows
- **Inertia:** Inertia in power systems refers to the energy stored in large synchronous generators, which gives them the tendency to remain rotating and historically has been a key source of grid reliability.
- **Price spread:** volume-weighted average captured discharging price minus charging price over a period
- **Variable renewables**: weather-dependent renewables i.e. wind and solar

B Abbreviations

- **BESS:** Battery Energy Storage System
- **CAPEX:** Capital expenditure
- **CCS**: Carbon, capture and storage
- **DS3**: Delivering a Secure, Sustainable Electricity System
- **FCR(-D/-N)**: Frequency containment reserves(-disturbance/normal)
- **GW(h):** Gigawatt (hour)
- **IRRs:** internal rate of return
- **I-SEM:** Integrated Single Electricity Market
- **MSD**: Mercato per il Servizio di Dispacciamento (Italian Ancillary services market)
- **MW(h):** Megawatt (hour)
- **NPV**: Net Present Value
- **OEM**: original equipment manufacturer
- **PICASSO:** The Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation
- **RES**: Renewable energy systems
- **TW(h):** Terawatt (hour)

Source: Aurora Energy Research

Details and disclaimer

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