

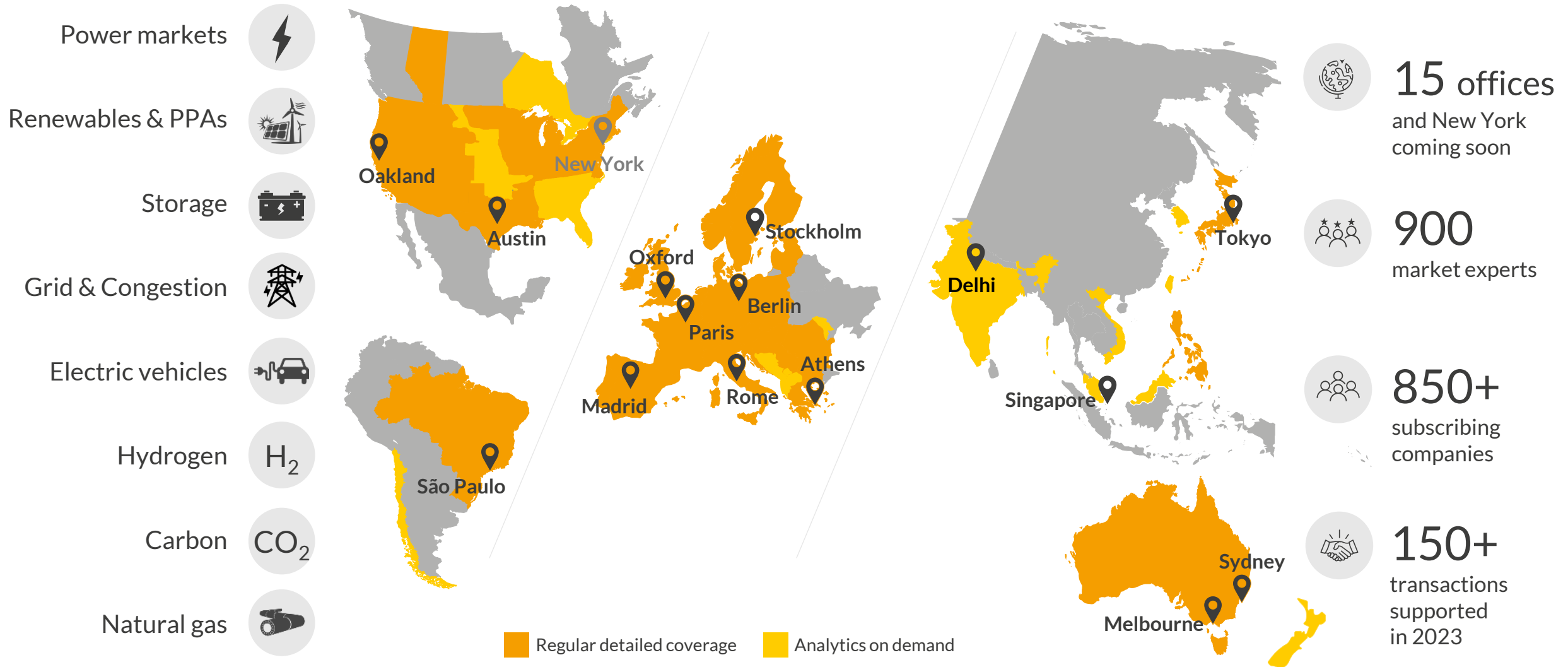
Charge Ahead: Riding the next Wave of Europe's Energy Storage investments

March 2025

Powered by  CHRONOS



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



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

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 AS¹ markets, including responding to market changes
- Capturing the role of weather in driving scarcity and AS¹ procurement – annual averages are irrelevant to storage economics, especially as renewables penetration increases
- Dispatching assets against multiple price series accounting for imperfect foresight, degradation, warranties, route to market, and asset characteristics

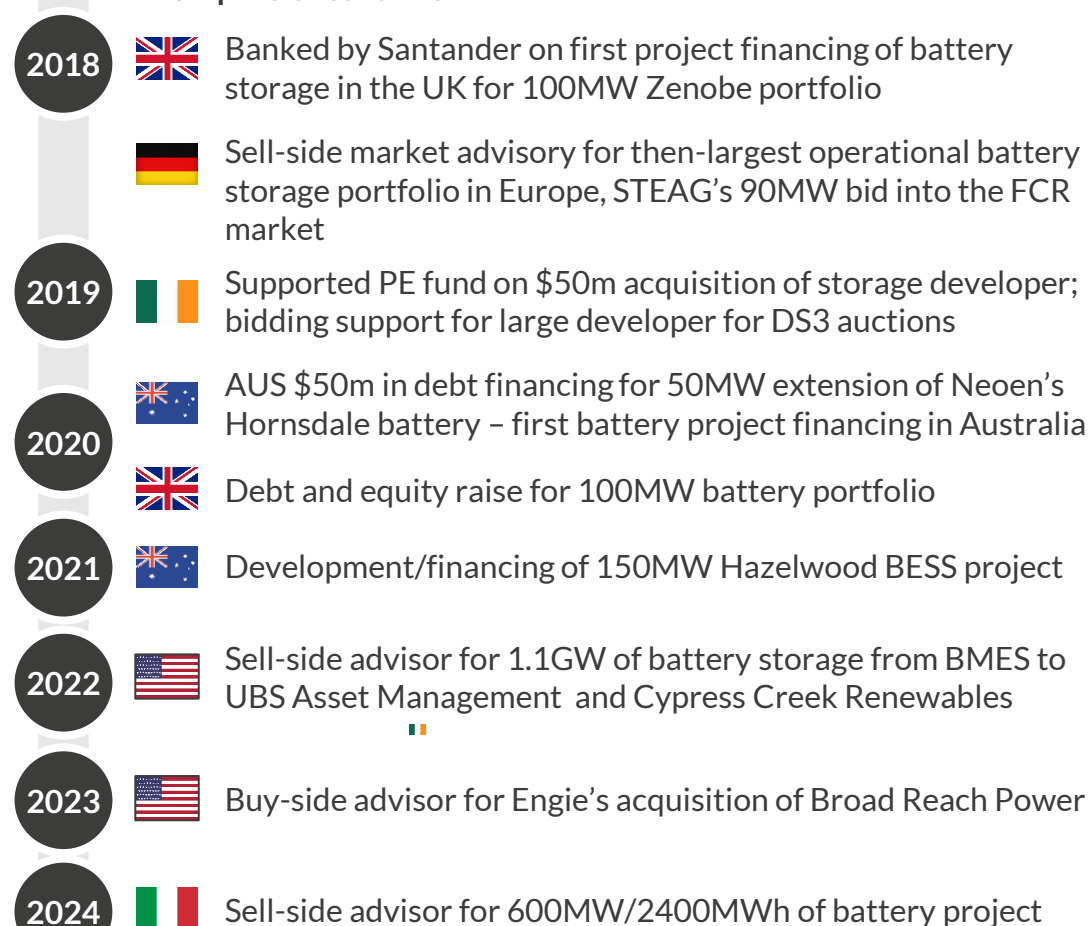
Future of the market
(*difficult to model*)

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



1) Ancillary Services.

European Battery Markets Attractiveness Report



Market Drivers: Key factors driving battery deployment in Europe, including renewables growth, thermal phaseout, and demand trends.



Market Outlook: Current installed BESS capacity, project pipeline, and grid connection status, alongside Aurora's forecast for battery buildout and investment through 2030 and 2050.



Regulatory Landscape: In-depth analysis of policy frameworks, revenue streams, risks, and future regulatory developments.



Revenue Potential: Evaluation of different revenue streams, including ancillary and wholesale markets, based on Aurora's in-depth modelling of battery economics.





Project Economics: Profitability drivers, country-specific insights, and the impact of different battery configurations on returns.



In addition to the report:

Databook: Includes the underlying metrics used for the attractiveness ranking. The databook is an **interactive tool**, which can be used to change the weighting of different categories and can thereby be adjusted to your needs.

90 Minute Workshop
with our Pan-European team

-  In depth coverage including project economics
-  Standard Coverage

Introducing the Aurora speakers



Jörn Richstein

Research Lead – Pan
European Power Markets



Eva Zimmermann

Lead Flexible Energy- Pan
European Power Markets



Ronak Parikh

Research Analyst – Pan
European Power Markets

Any questions? Get in touch!

Bea.Dunlop@auroraer.com

I. Introduction

II. Market size and outlook

III. Policy environment

IV. Revenue streams

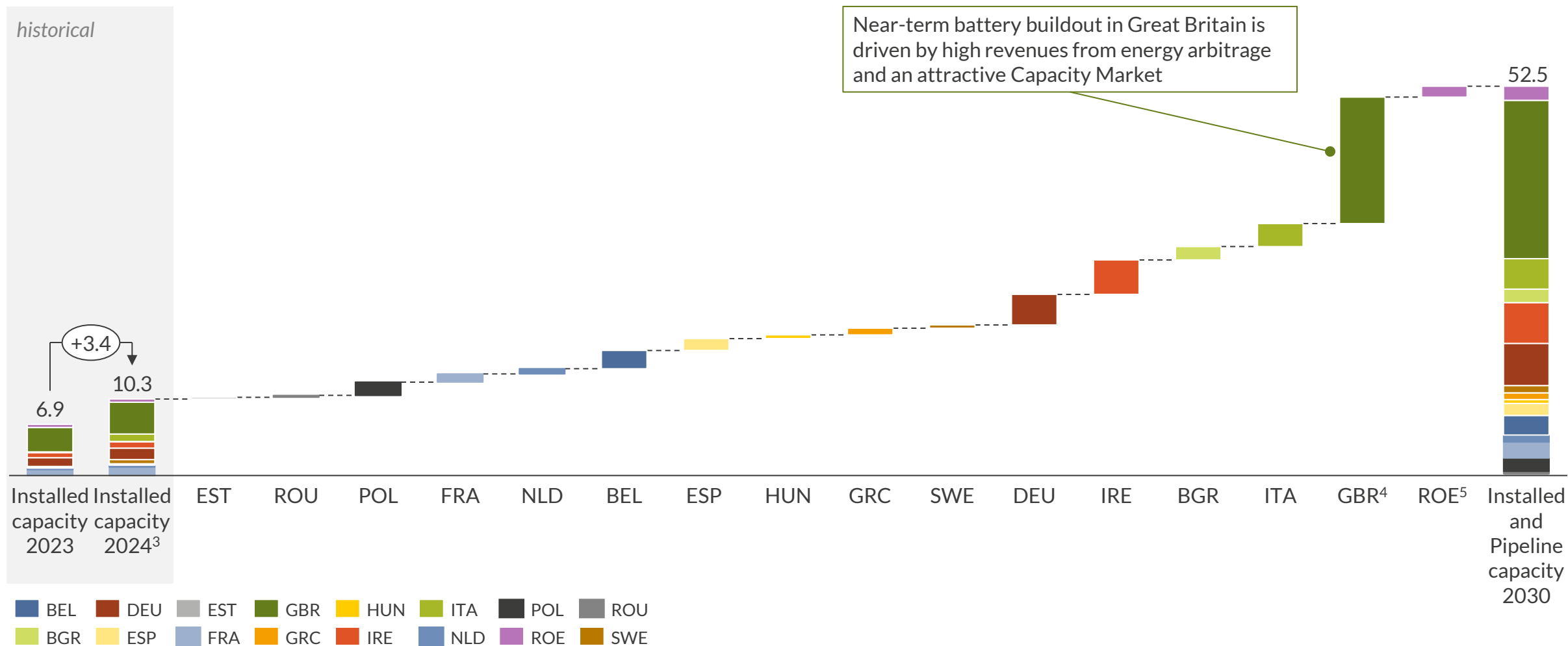
V. Project economics

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Full delivery of the current high probability pipeline would see battery capacity in Europe grow to over 52 GW by 2030

Near-term project pipeline of grid-scale batteries¹
GW, nameplate²

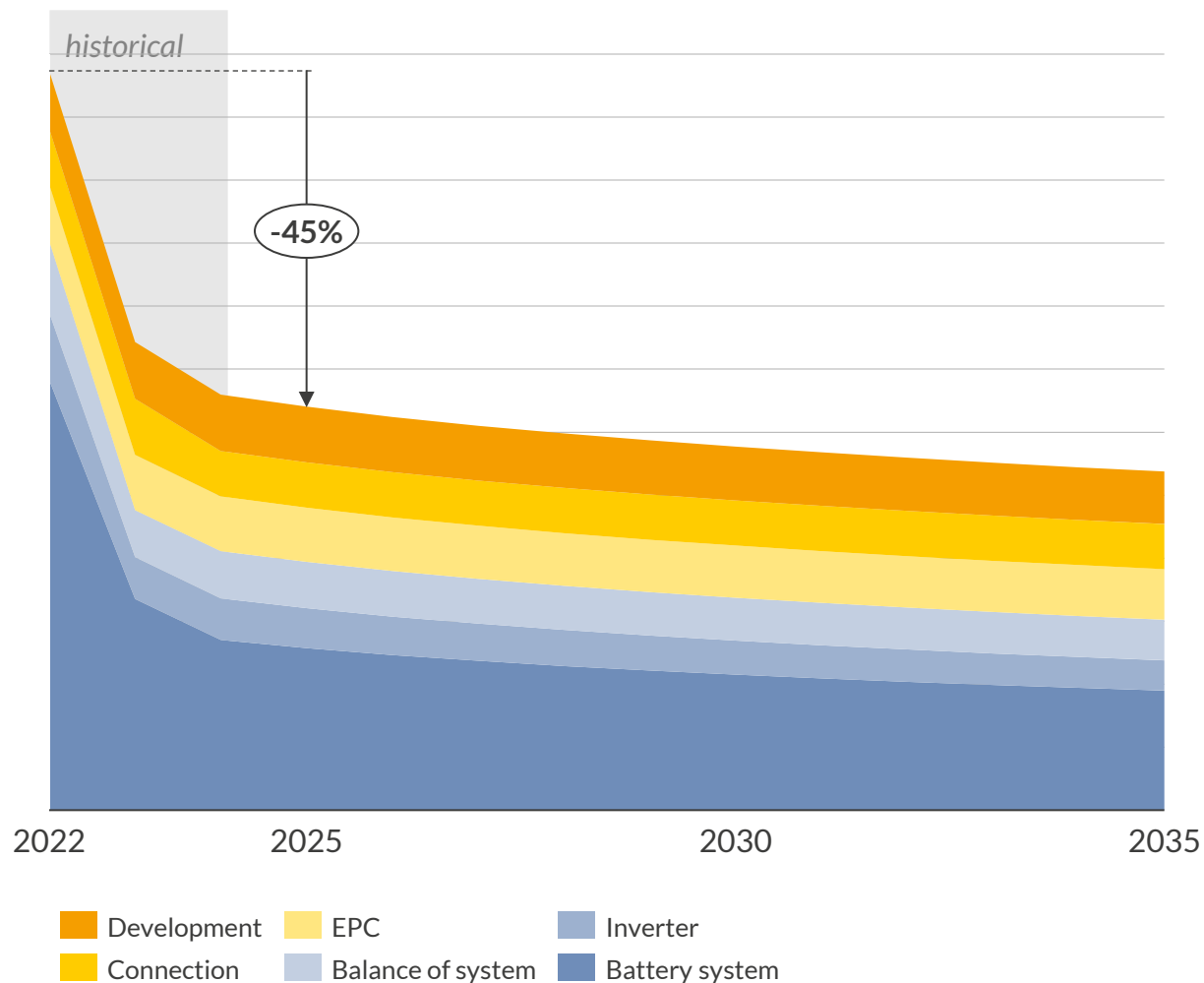


1) Includes projects with a very high likelihood of realisation, e.g. agreed connections and contracts and granted planning permissions, or in construction; 2) New-build, nameplate battery capacity presented i.e. capacity before any de-rating factor is applied; 3) As of November 2024; 4) As of Q3 2024 Renewable Energy Planning Database; 5) Rest of Europe.

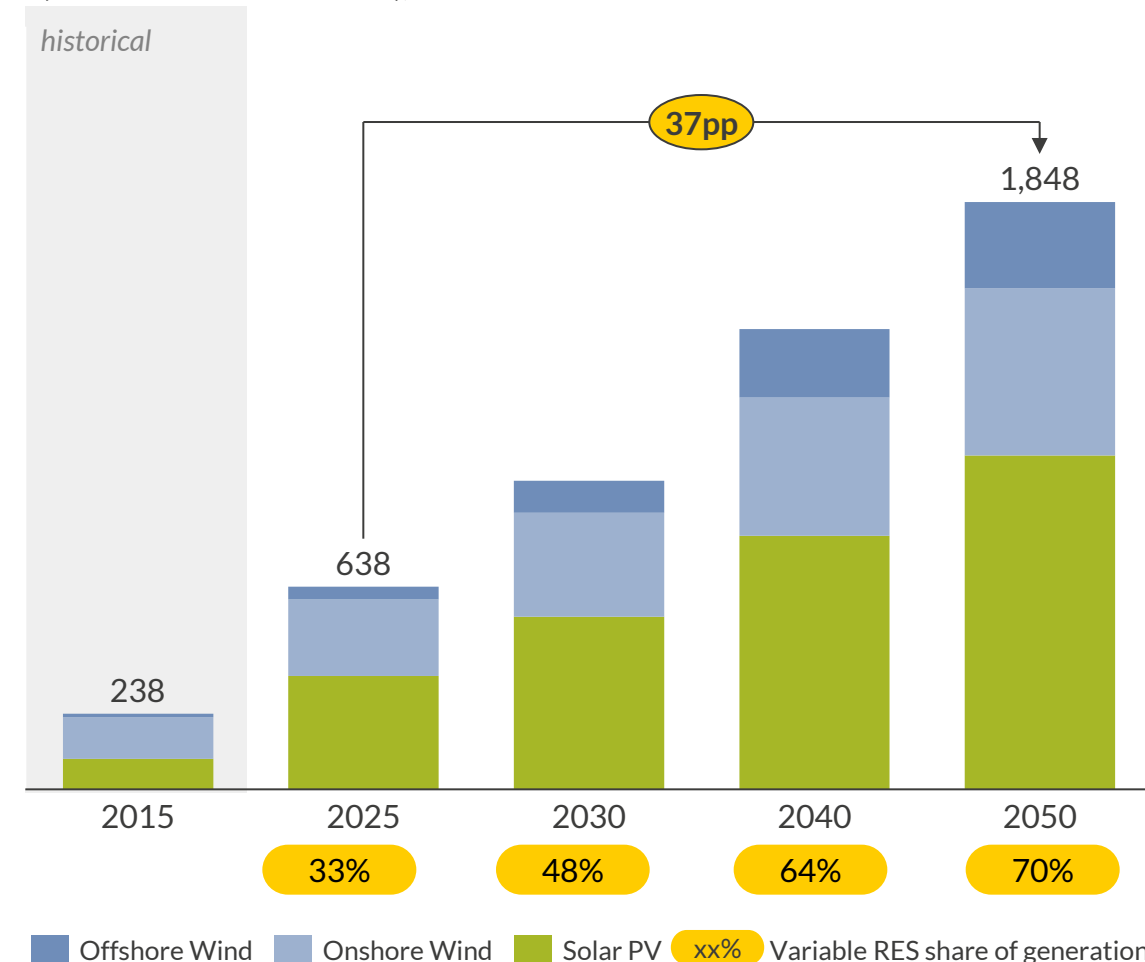
Source: Aurora Energy Research, Renewable Energy Planning Database

Li-ion batteries CAPEX is decreasing, while renewables deployment is ramping up

Li-ion battery total system costs¹ – 2h asset
€/kW, real 2023



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



1) Nameplate capacity 2) Ranking and market attractive analyses in this report are based on 2024 forecast.

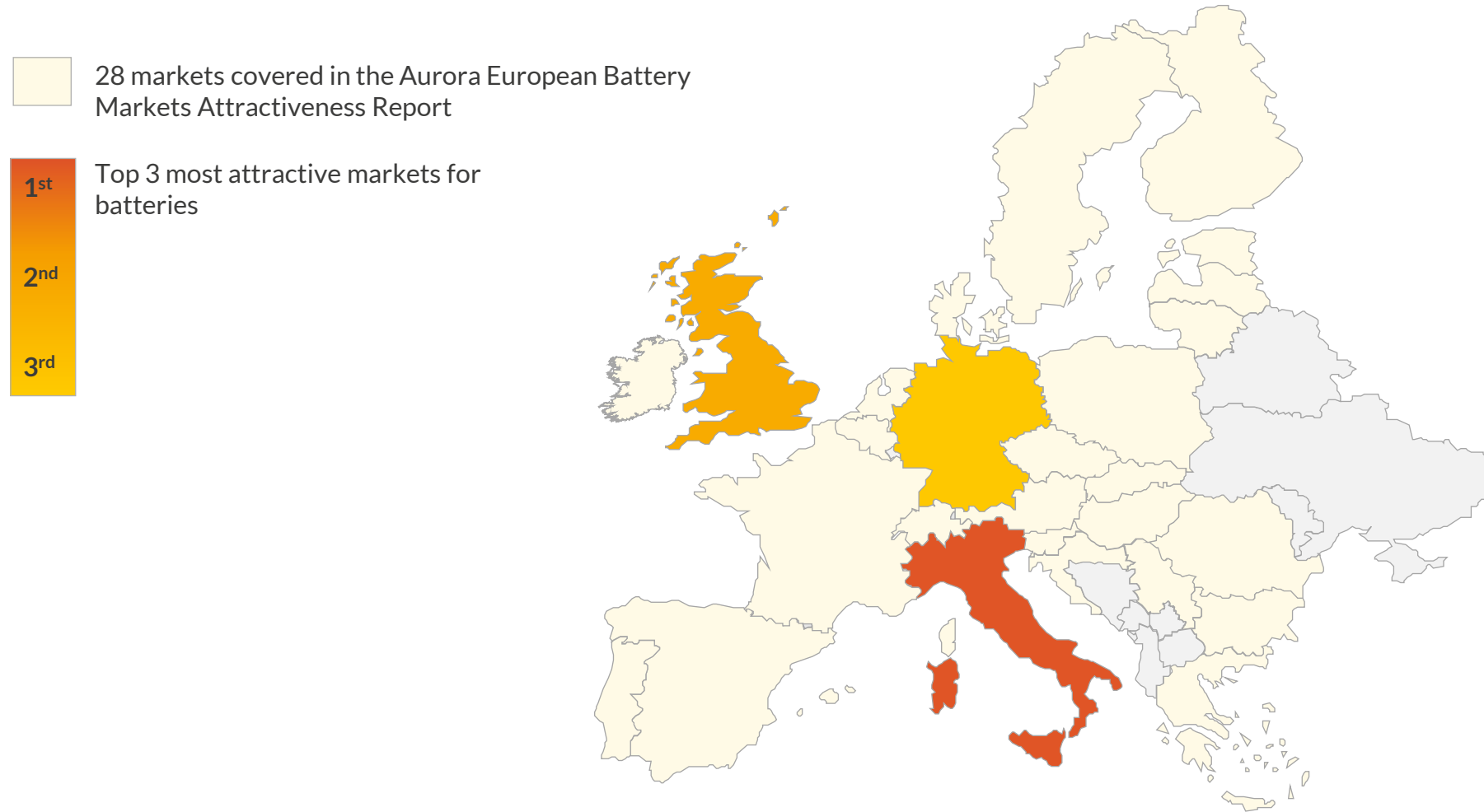
Aurora's rating combines 11 metrics to derive an overall attractiveness score for 28 European grid scale battery markets

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

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

1) Aggregation of Distributed Energy Resources, such as behind-the-meter batteries and demand-side response

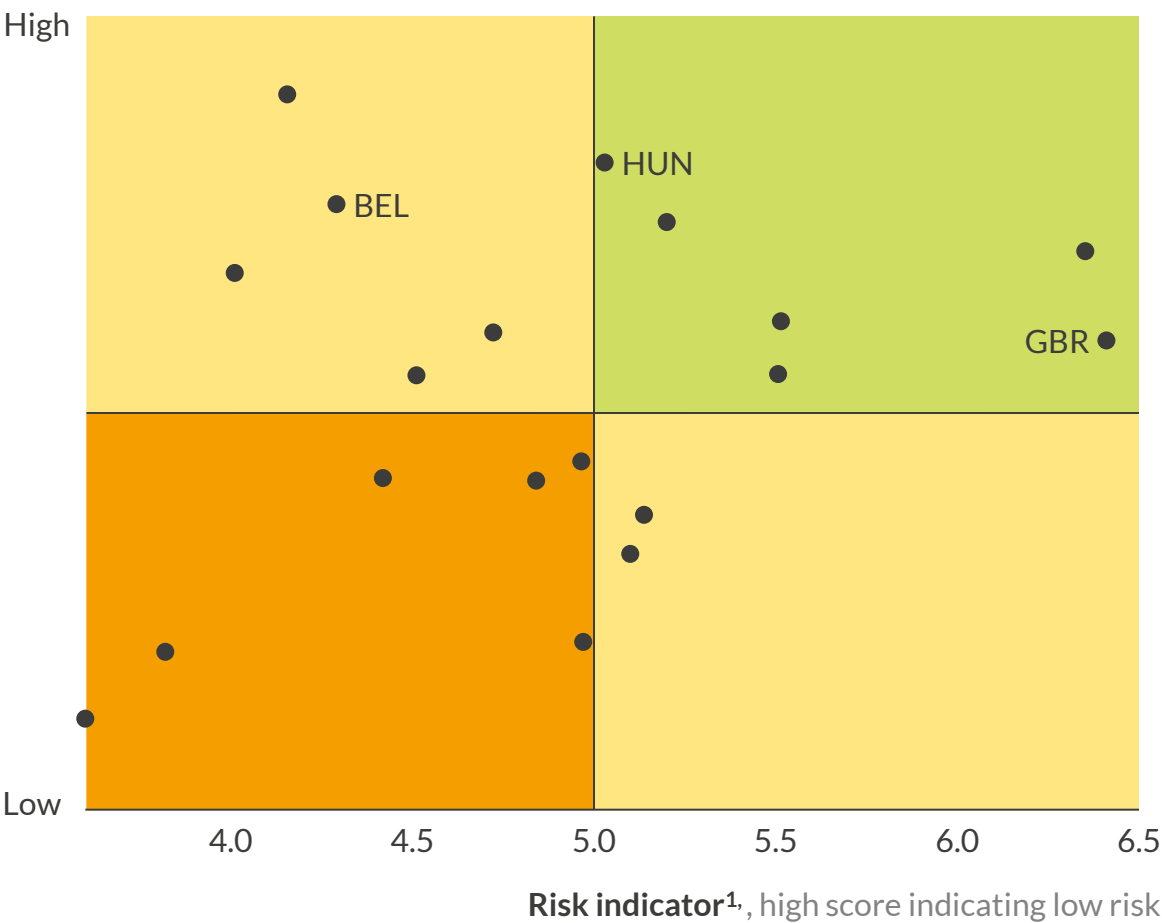
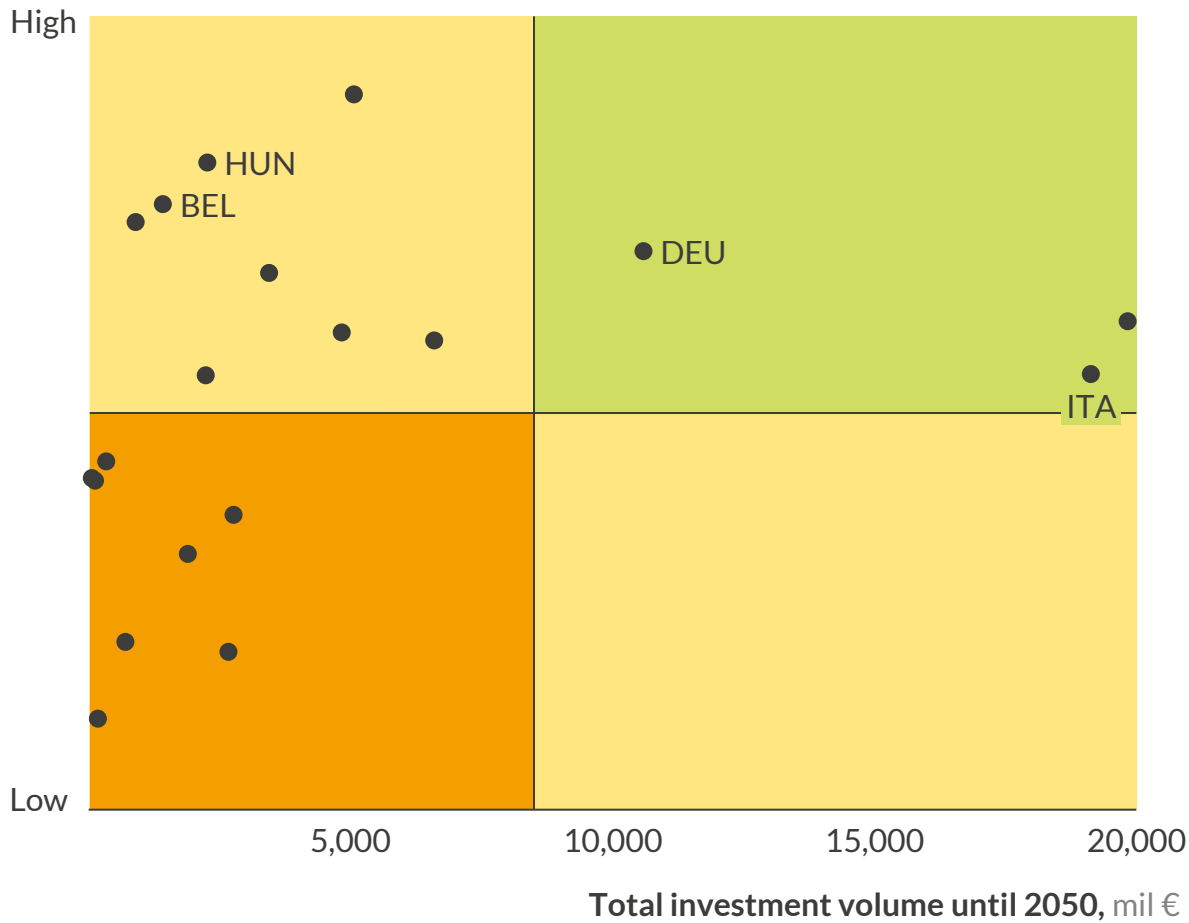
Based on Auroras ranking, the top three most attractive markets for grid-scale battery storage are Italy, Great Britain and Germany



Belgium, Hungary are attractive for smaller scale investors with a higher risk appetite

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Project economics
%, IRR (real), pre-tax



1) Based on renewables buildout, installed battery capacity, contracted revenue streams, ease of getting a grid connection, competitive risk and ancillary service saturation.

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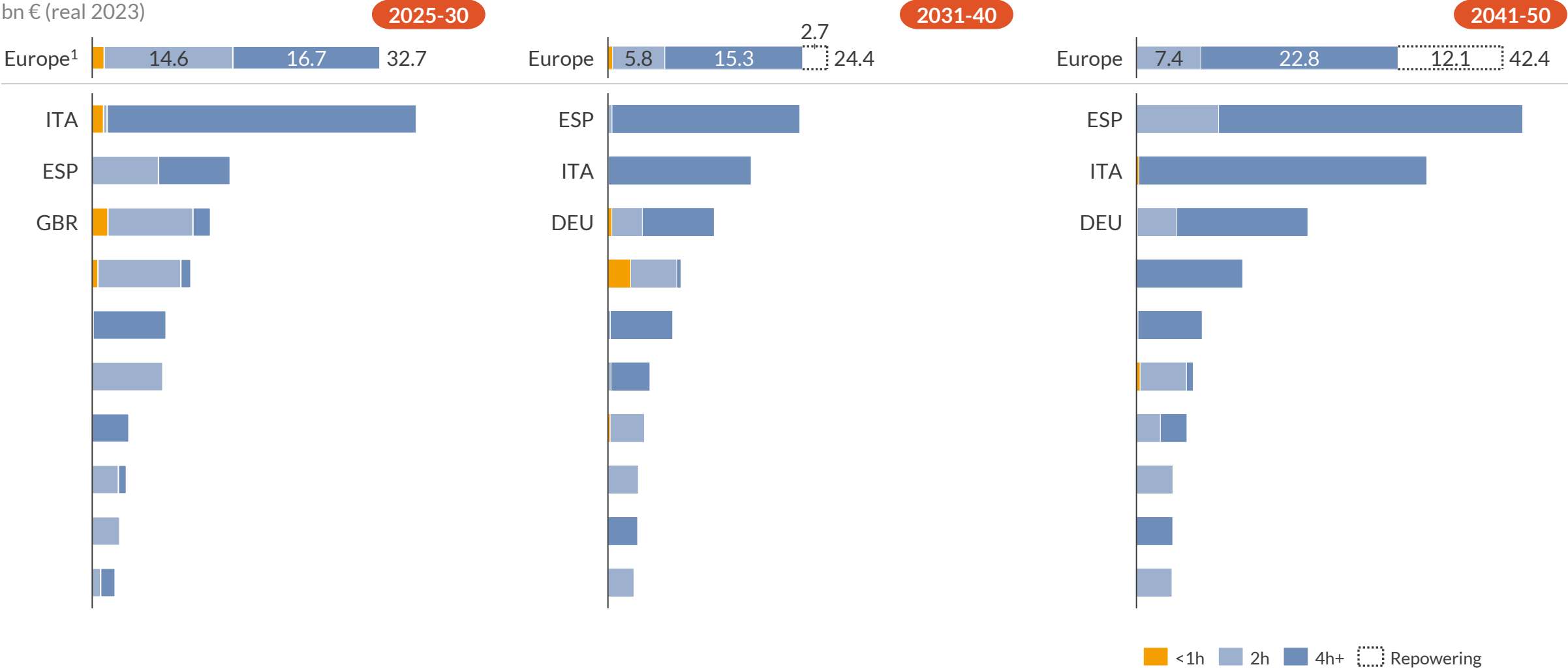
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The projected battery capacity additions represent a cumulative investment opportunity of almost 100bn€ between 2025-50

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



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

Announced pipeline capacity exhausts 90% of Aurora's 2030 forecast, though opportunity remains in some markets

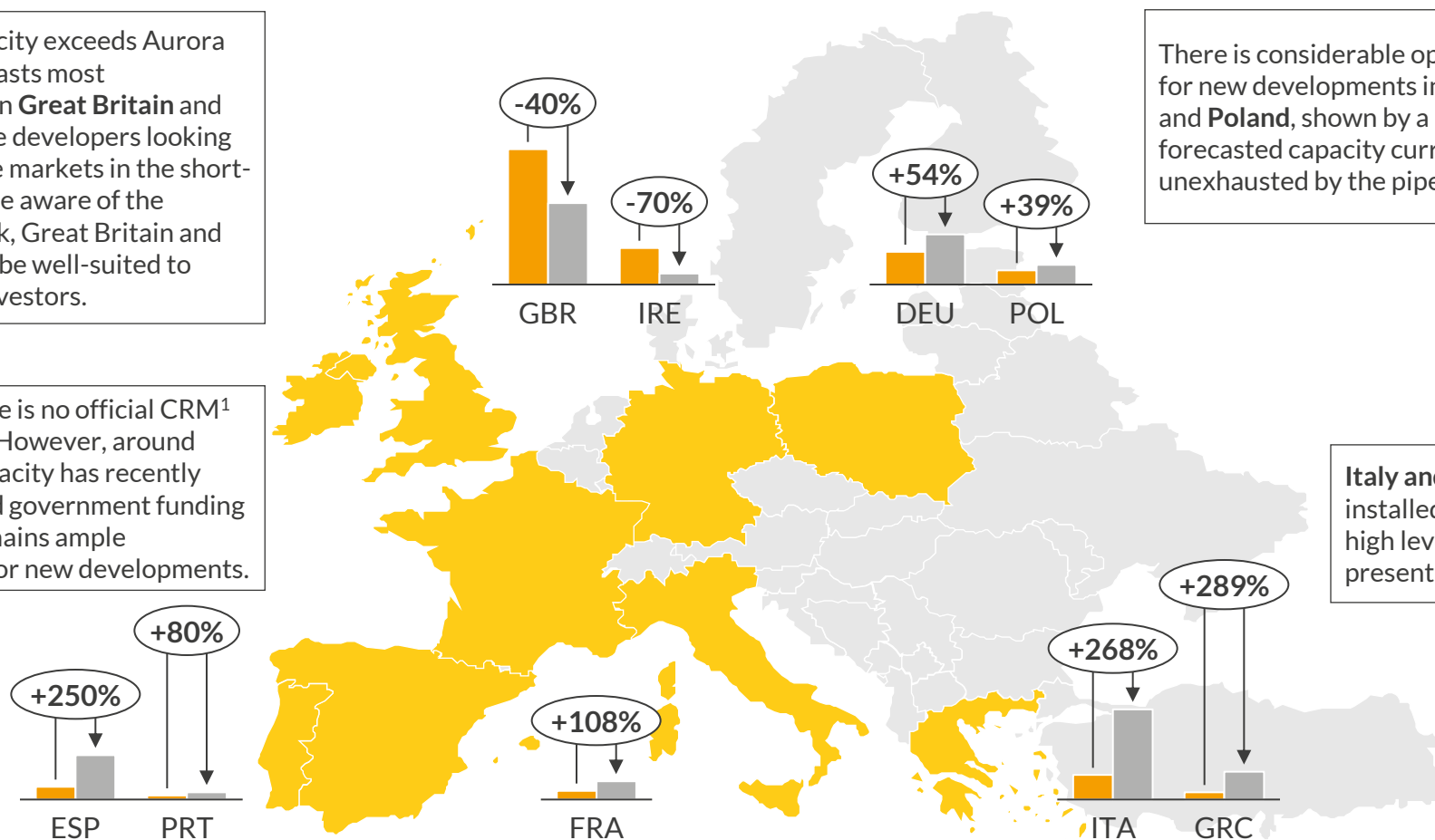
Pipeline vs Forecasted Capacity – Europe

Pipeline capacity exceeds Aurora Central forecasts most dramatically in **Great Britain** and **Ireland**. While developers looking to enter these markets in the short-term should be aware of the saturation risk, Great Britain and Ireland could be well-suited to later-stage investors.

In **Iberia**, there is no official CRM¹ for BESS yet. However, around 2.1GW of capacity has recently been awarded government funding and there remains ample opportunity for new developments.

There is considerable opportunity for new developments in **Germany** and **Poland**, shown by a level of forecasted capacity currently unexhausted by the pipeline.

Italy and **Greece's** low current installed capacity, coupled with high levels of battery build out, present sizeable markets to enter.



 Announced pipeline capacity 2030²  Buildout 2030 - Aurora Central

1) Capacity Remuneration Mechanism; 2) Includes projects with a very high likelihood of realisation, e.g. agreed connections and contracts, granted planning permissions or under construction.

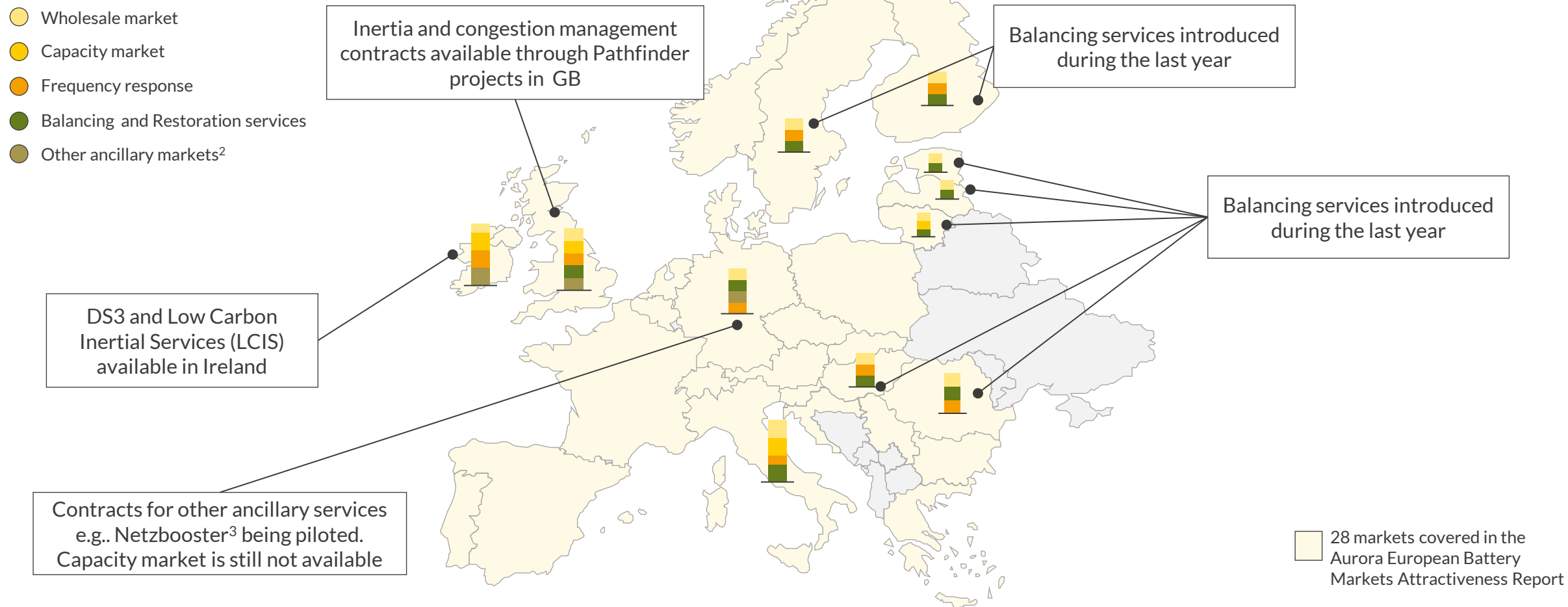
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Revenue stacking across markets is fundamental for battery profitability, with frequency response services being very valuable








Availability of capacity, balancing and ancillary markets in Europe¹

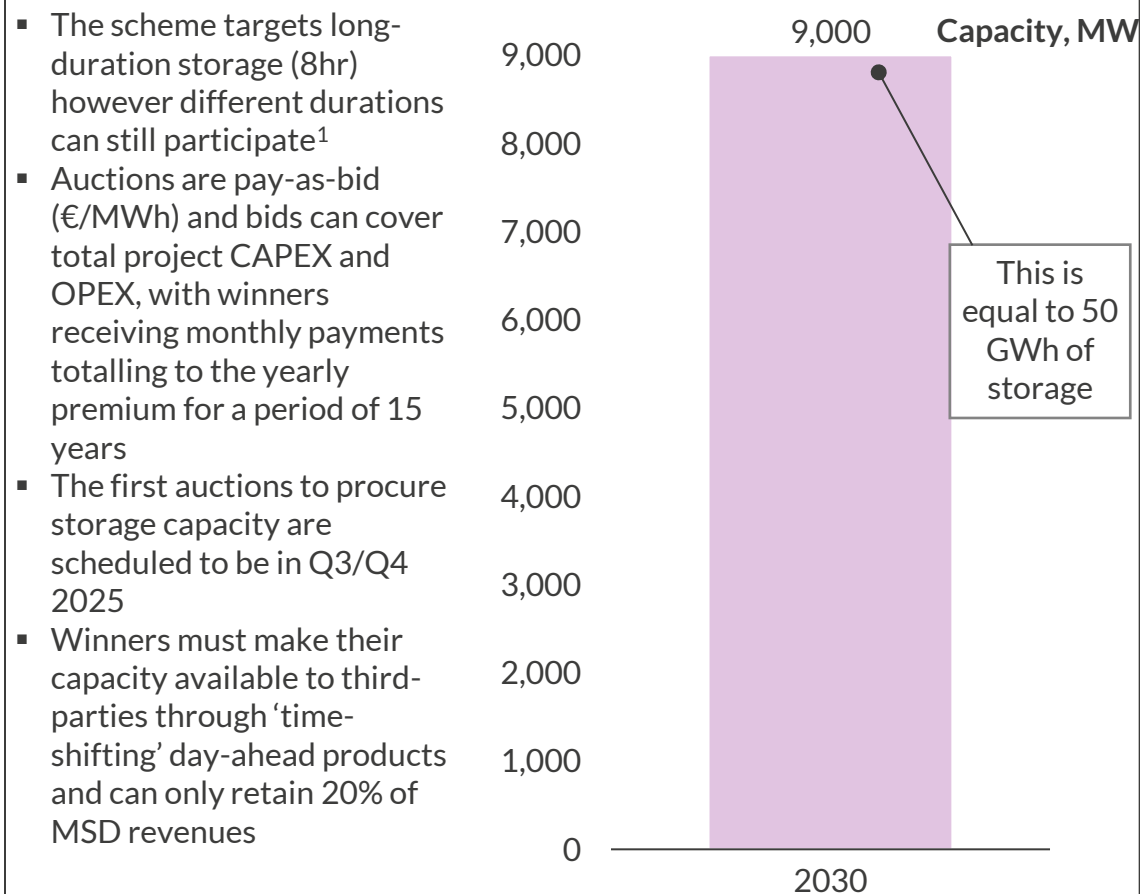


1) Showing available and relevant markets for batteries. Half bars indicate where markets are partially available; 2) Includes inertia, black start, technical restrictions, congestion management etc.; 3) Netzbooster is a non-stackable revenue stream.

Italy's MACSE scheme aims to procure 9GW of capacity by 2030; additional schemes have the potential to procure almost 2.5GW

Available subsidy schemes in Europe

	Italy:	MACSE
	Germany:	Innovation Auctions
	Greece:	National BESS auctions
	Spain:	PERTE ERHA calls
	Hungary:	Storage CfD
	Bulgaria:	Co-located and Standalone storage grants
	Romania:	Battery storage state aid



1) Coefficients will be applied to applicants' bids to ensure comparability of bids across different durations, but zonal coefficients are no longer part of the scheme.

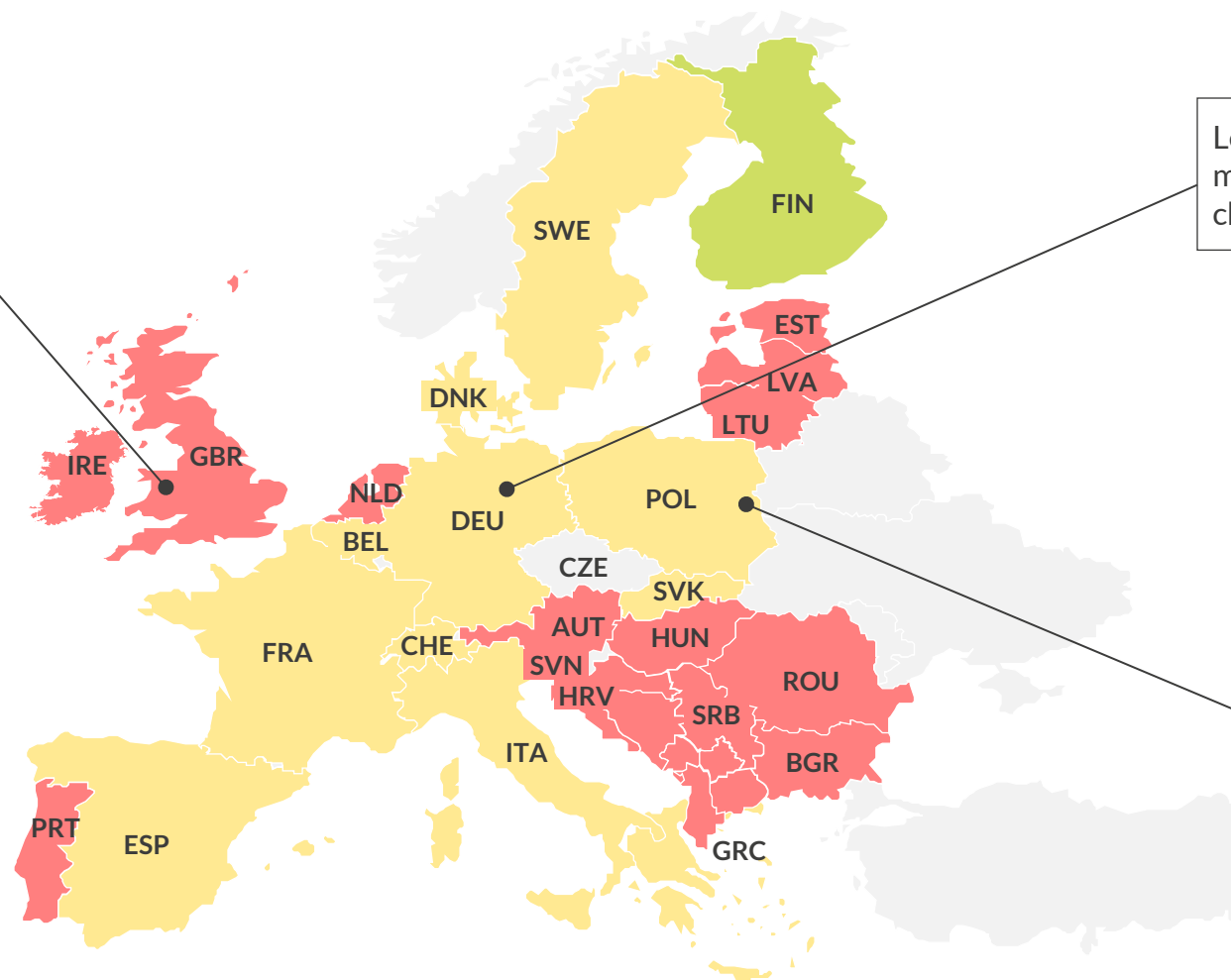
Grid connection times tend to pose a significant hurdle to battery deployment, with initiatives being taken to reduce the wait

Grid connection queue¹ is under wide reform. New initiatives from NESO—prioritizing projects closer to readiness and incorporating the flexibility of batteries in network modelling—may accelerate connections. However, the overall outlook remains uncertain.

Lengthy administrative procedures making grid connections increasingly challenging.

Grid connection rating

-  Poor
-  Average
-  Good



Cable pooling² legislation now in place should enable easier connections. However, there have recently been many grid connection rejections due to technical or economic factors (82 GW rejected capacities in 2023).

1) Grid connection queue for renewable capacity; 2) Cable pooling is defined as a single grid connection being able to accommodate multiple power generating sources.

Sources: Aurora Energy Research

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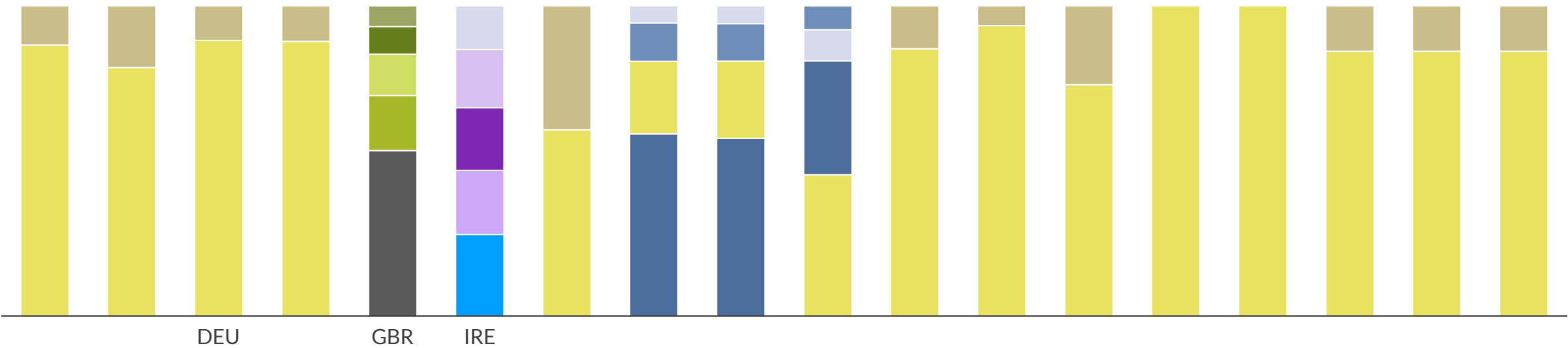
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Installed battery capacity in 2024 is insufficient to saturate most Ancillary Services yet some, such as Great Britain, come close...

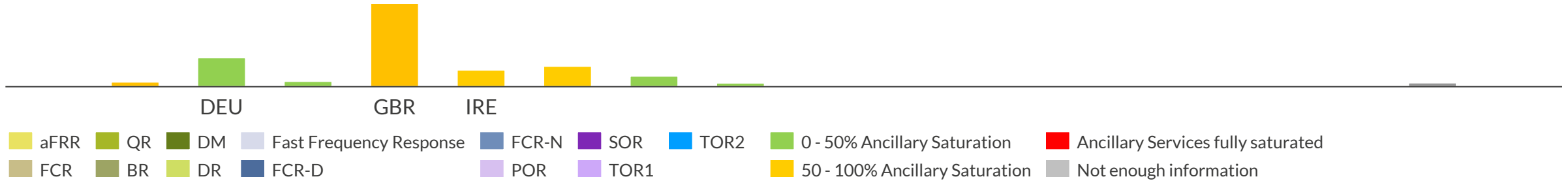
2024 Total Ancillary Service Procurement

MW



2024 Total Battery Capacity

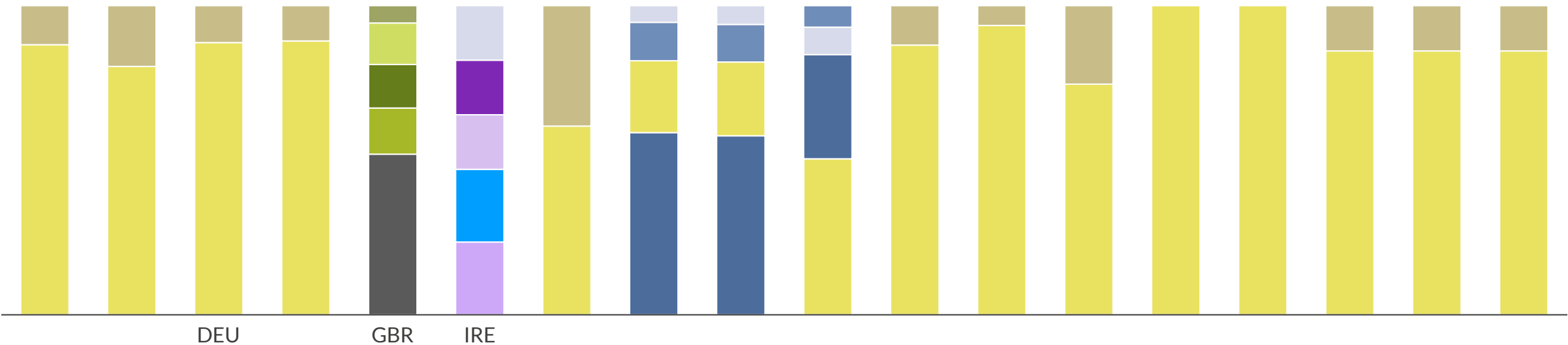
MW



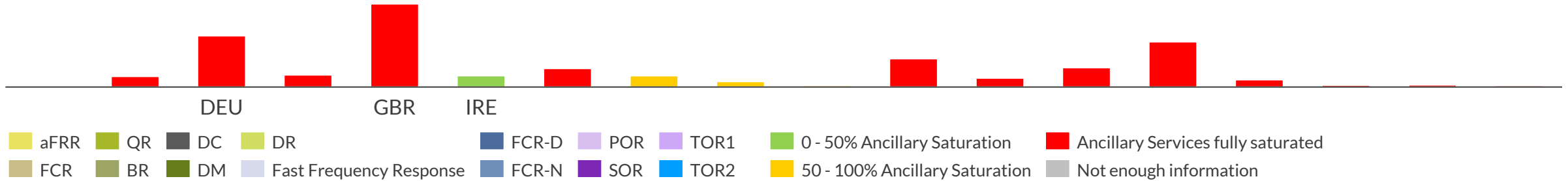
aFRR QR DM Fast Frequency Response FCR-N SOR TOR2 0 - 50% Ancillary Saturation Ancillary Services fully saturated
FCR BR DR FCR-D POR TOR1 50 - 100% Ancillary Saturation Not enough information

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

2030 Total Ancillary Service Procurement
MW

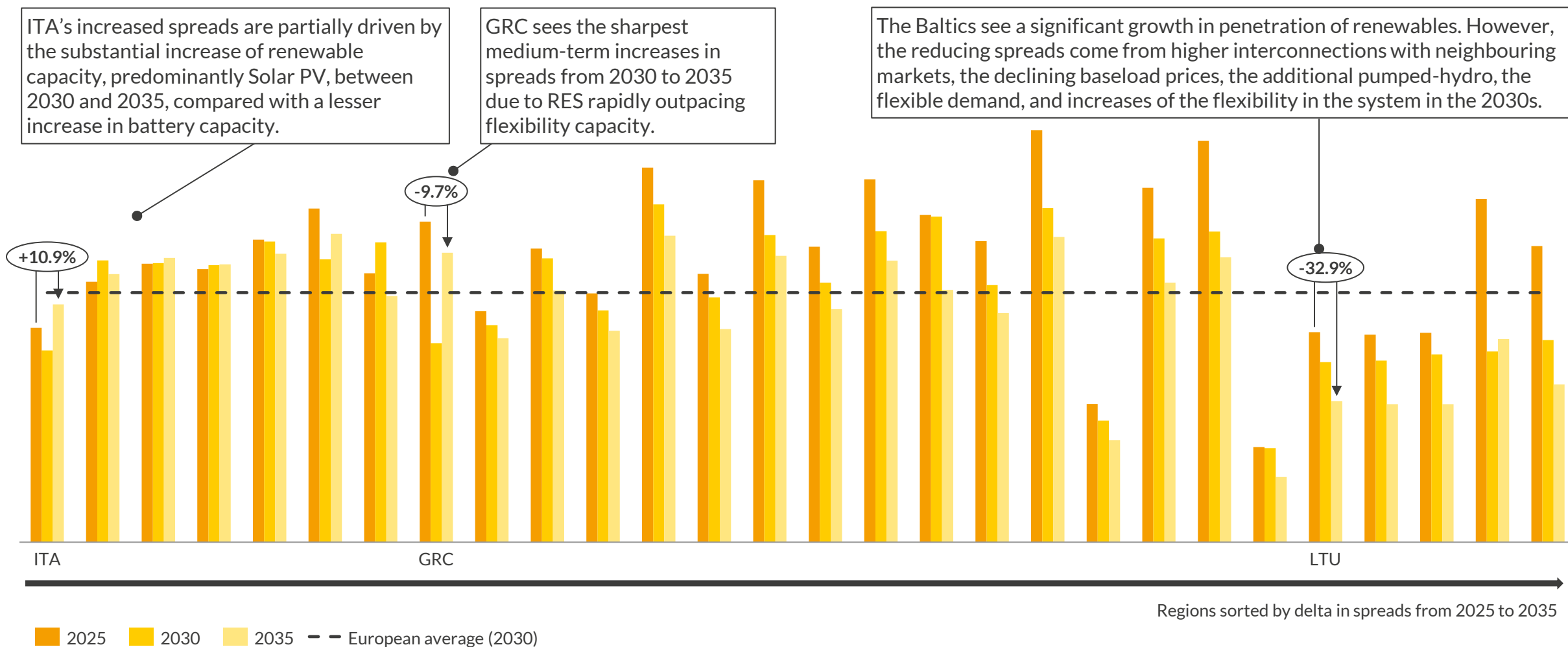


2030 Total Battery Capacity
MW



Most European regions see flexible buildout eclipse renewables growth, putting downwards pressure on spreads

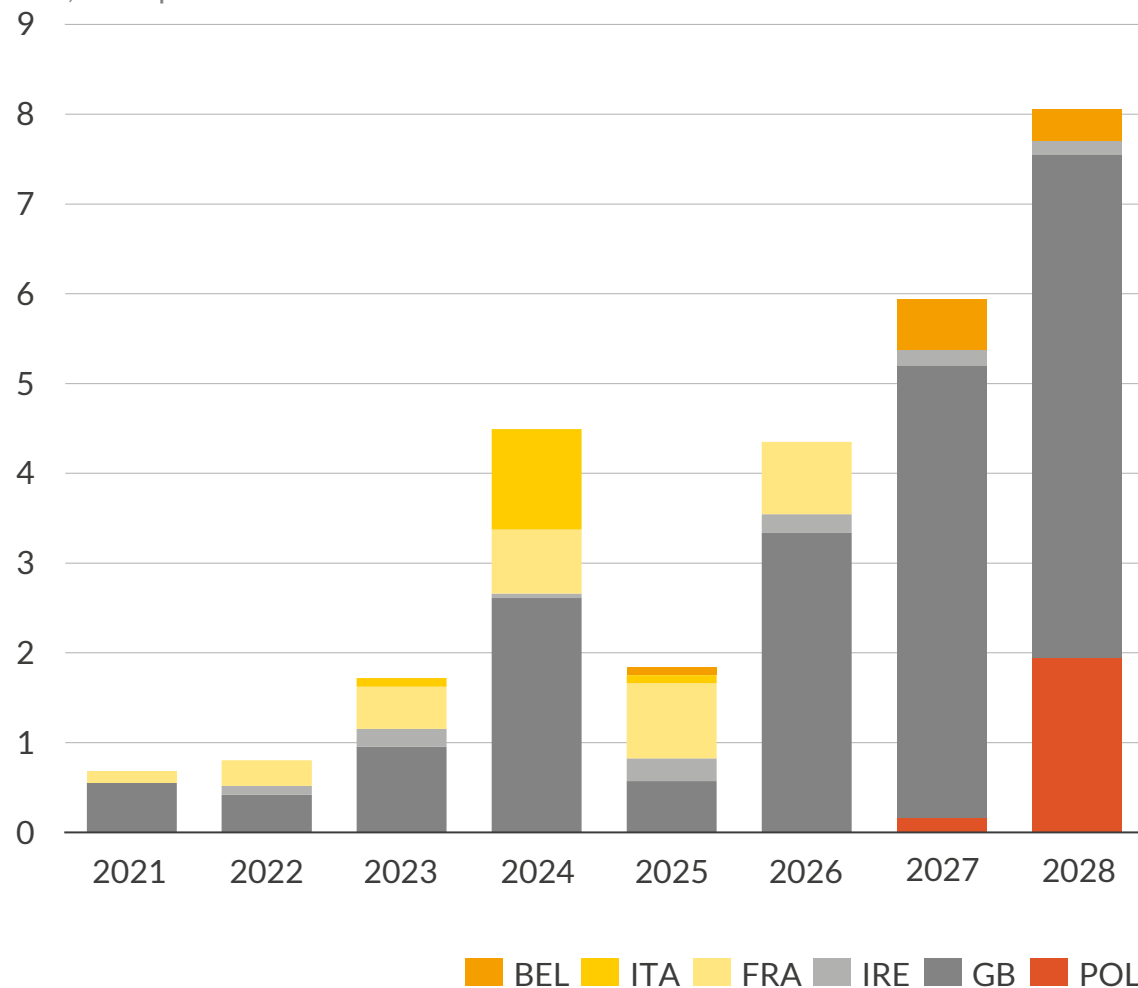
Average daily 1h¹ wholesale day-ahead market price spread
€/MWh (real 2023)



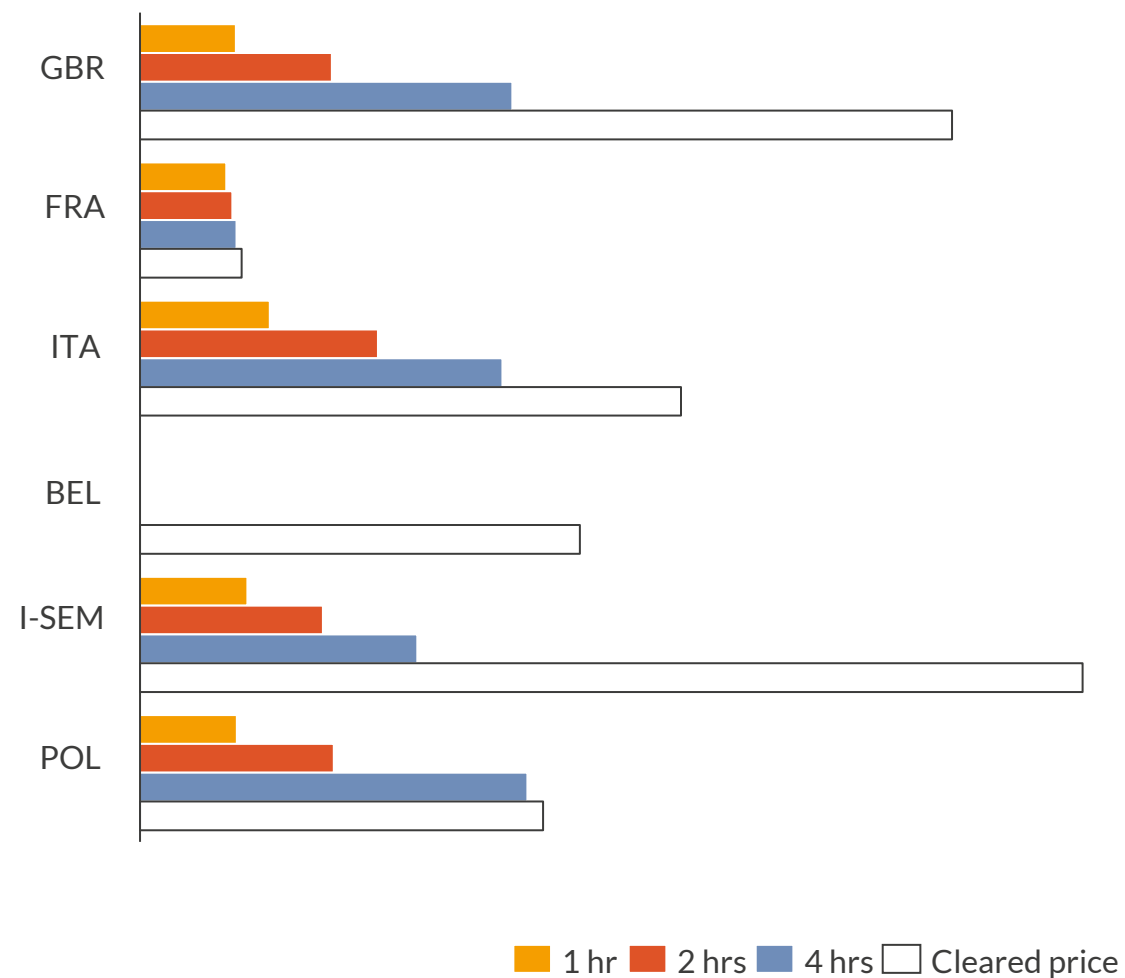
1) Yearly average of the daily spreads. The daily spreads are the difference between the average of the highest 1h and the lowest 1h for each day.

Capacity markets support over 27 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 2023)



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

1 Revenue streams



The interplay between revenue stack, battery duration and market saturation impacts IRR differently across Europe.

3 Battery duration



Higher duration assets require more upfront investment but often have higher earning potential.

5 Commercial Operations Date



Earlier entry typically translates to higher earnings in ancillary markets, as later years see increased competition.

7 Subsidy schemes



Contracted revenues can increase investability by providing long-term security to asset owners.

9 AI trading



Automated trading on the Intraday market can bolster business case but comes with uncertainties.

2 Regulatory factors



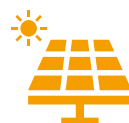
Margins can increase over time when innovative regulatory changes are introduced, contrary to prevailing trends.

4 Price zones



Proximity to renewable generation and power demand can greatly influence project profitability.

6 Co-location



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

8 Repowering



Repowering increases state-of-health and prolongs the period of high revenues, with limited cost increase.

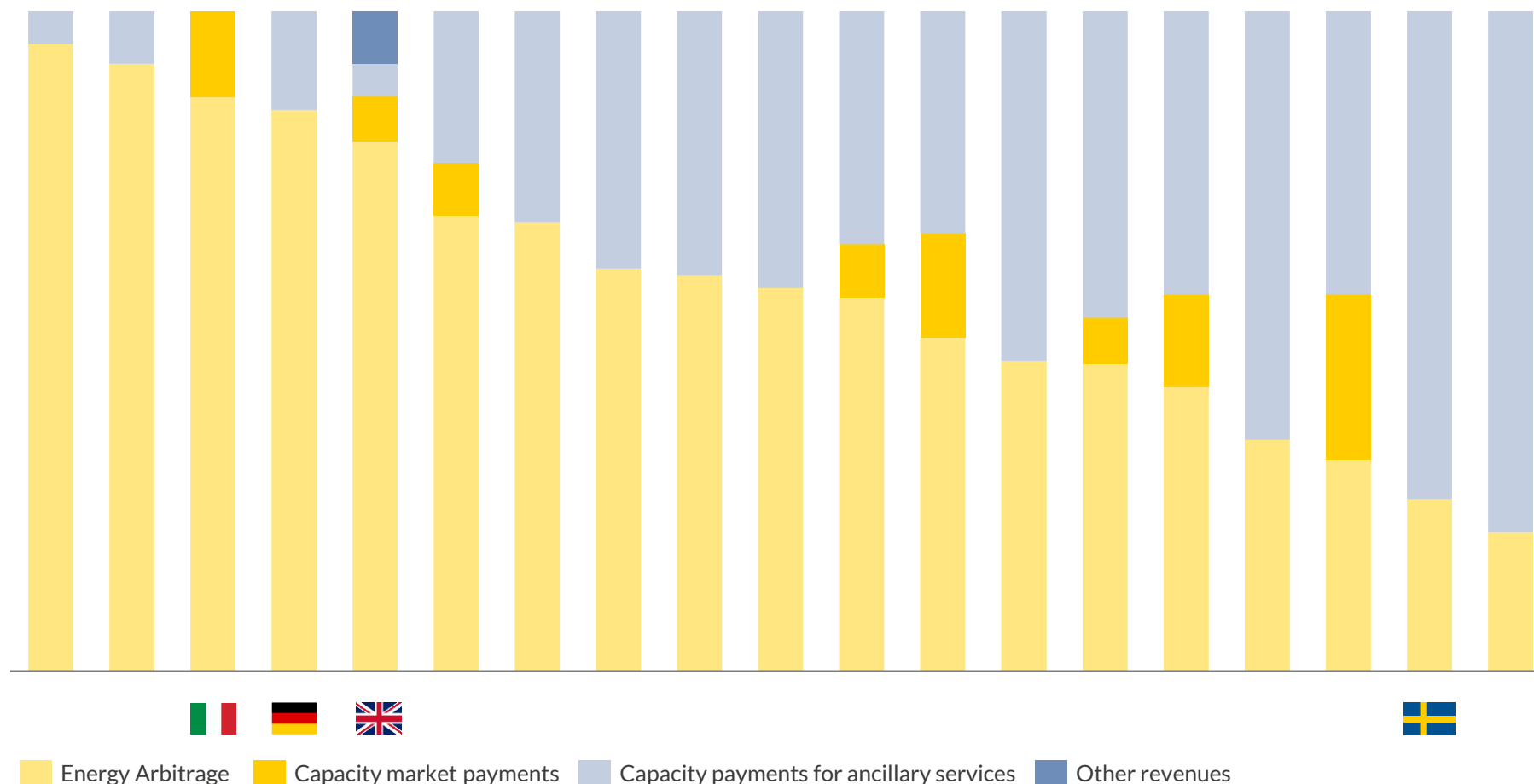
10 Market developments



Aurora's diverse scenario range helps to navigate market ambiguities and risks.

Depending on policy and market structure, profitability can be achieved through different compositions of revenue stacks

Average composition of gross margin stack for 2h duration battery¹
% of 2027/28 – 2041



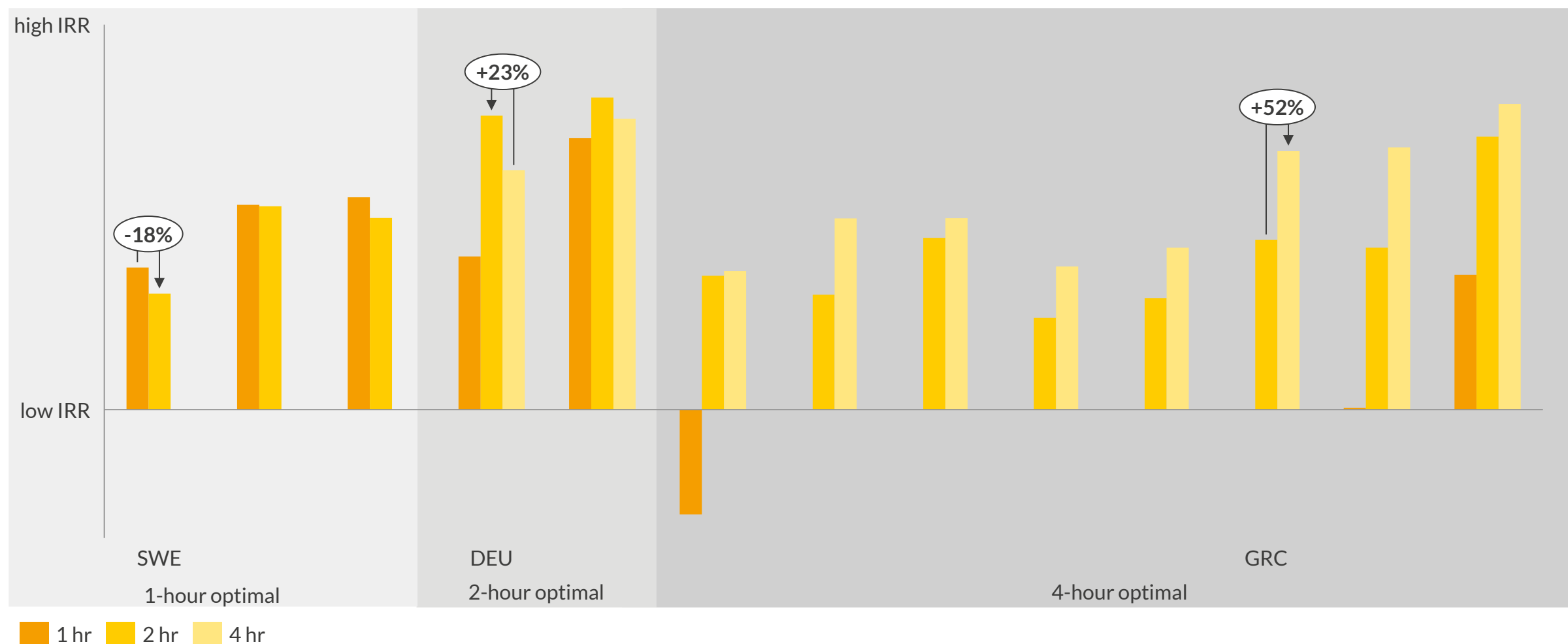
1) Shown for a representative standalone battery with 2027/28 entry year.

- Energy arbitrage and capacity-based ancillary services are typically the main sources of revenues for batteries across Europe.
- While capacity markets provide long term contract revenues for batteries, this typically makes up a smaller share of the gross margin stack and is dependent on the storage de-rating factors.
- Energy arbitrage revenues typically make up a larger share of the gross margin stack for 2 hr batteries due to the longer timeframe available for charging and discharging, providing increased ability to take advantage of arbitrage opportunities.

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

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

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1) Standard case represents standalone business cases without repowering for assets optimising among energy arbitrage, capacity-based ancillary services, and capacity markets cashflow. IRRs are based on Aurora's internal cost assumptions.

1. Aurora's European Battery Markets Attractiveness Report sees total capacity grow fivefold to 55GW by 2030, representing a cumulative investment of over 33bn€.
2. Based on Aurora's analysis, considering the most relevant drivers impacting battery business cases, including power market drivers, markets design and policy environment, the most attractive markets for BESS in Europe are **Italy, Great Britain and Germany**.
3. At the same time, there are smaller markets, which will have lower investment volumes and higher risk, but promising project economics such as **Greece, Hungary and Belgium**.
4. A strong storage pipeline throughout Europe emphasises the need and attractiveness of BESS investments. However, in some markets there is still space for greenfield projects, such as **Spain or Italy**.
5. The regulatory landscape is still fragmented throughout Europe, highly impacting the potential of battery investments in the different regions.
6. Many strategies and battery set ups can lead to profitability, depending on the region, as the composition of batteries' gross margin stack in Europe is mixed.

Want to see the whole report?

Get in touch!

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CHRONOS Battery valuations, perfected

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

Thorough: Accounts for all site-specific value drivers

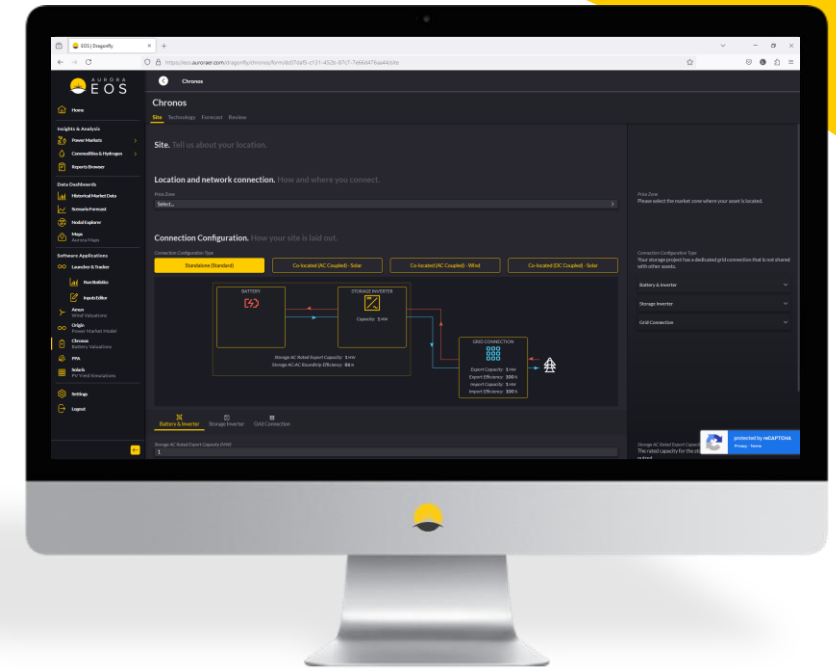
Reliable: Backed by Aurora's trusted forecasts and team of experts

Bankable: Methodology recognised by banks and investors, with reliance available

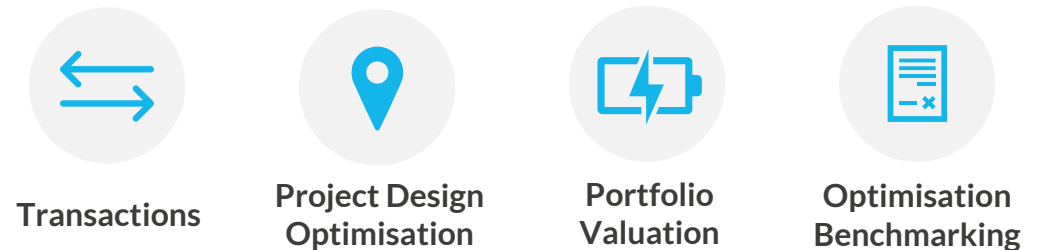
Comprehensive UX: Intuitive interface that empowers user driven analyses

Efficient: Evaluate as many opportunities or scenarios as you require, without any consultancy lead times, for just one yearly fee

Intuitive 4-step process:



What can Chronos be used for?



Trusted by industry leaders:

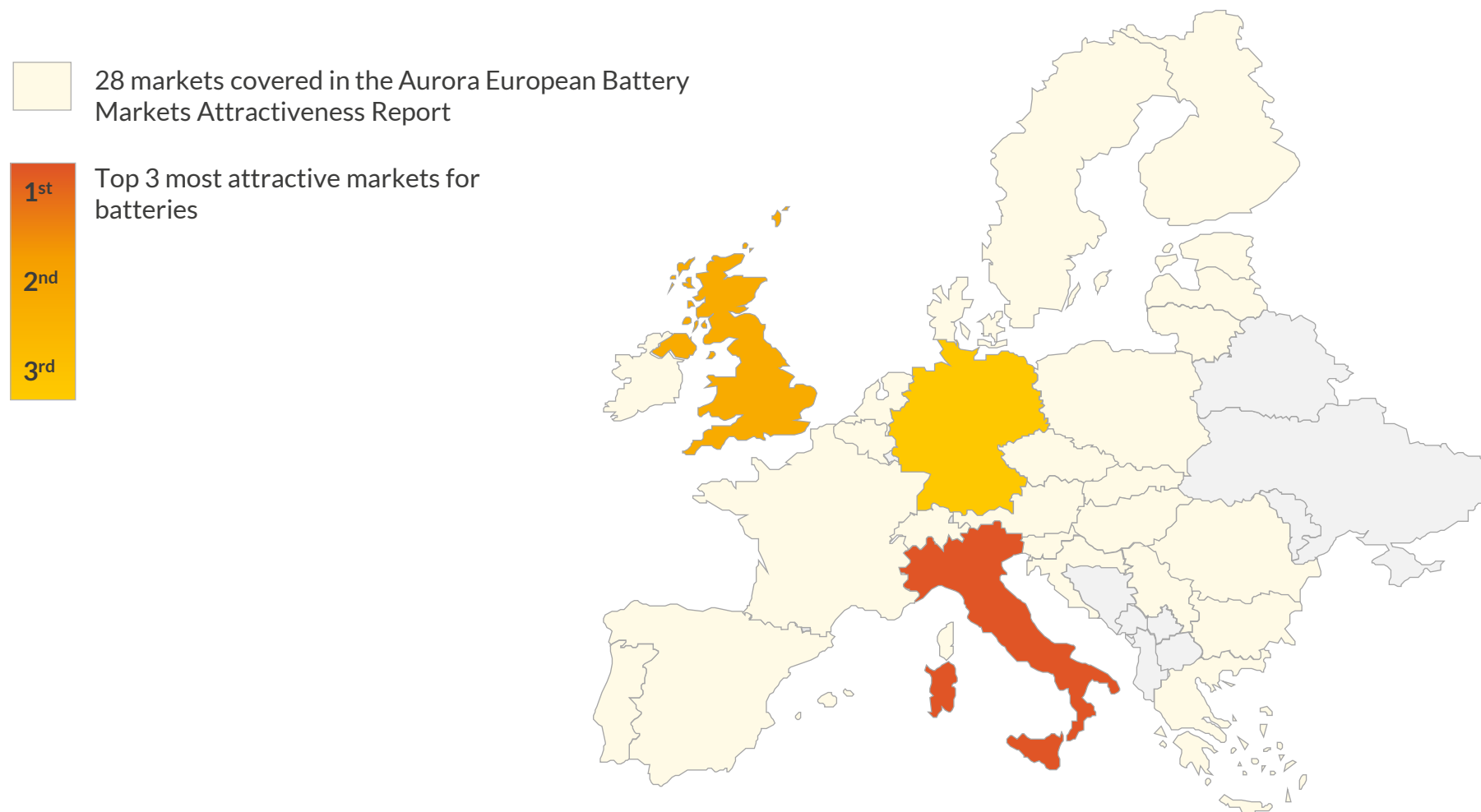


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Based on Auroras ranking, the top three most attractive markets for grid-scale battery storage are Italy, Great Britain and Germany



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E N E R G Y R E S E A R C H