

The Iberian Example in the Energy Transition

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Aurora Energy Research

- I. Introduction to Aurora
- II. Act I: The Success Story
- III. Act II: The Challenges
- IV. Act III: What Comes Next

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Renewables & PPAs



Natural Gas



Storage

CO₂

Carbon



Electric Vehicles

H₂

Hydrogen



19

Offices



1200+

Subscribing
companies



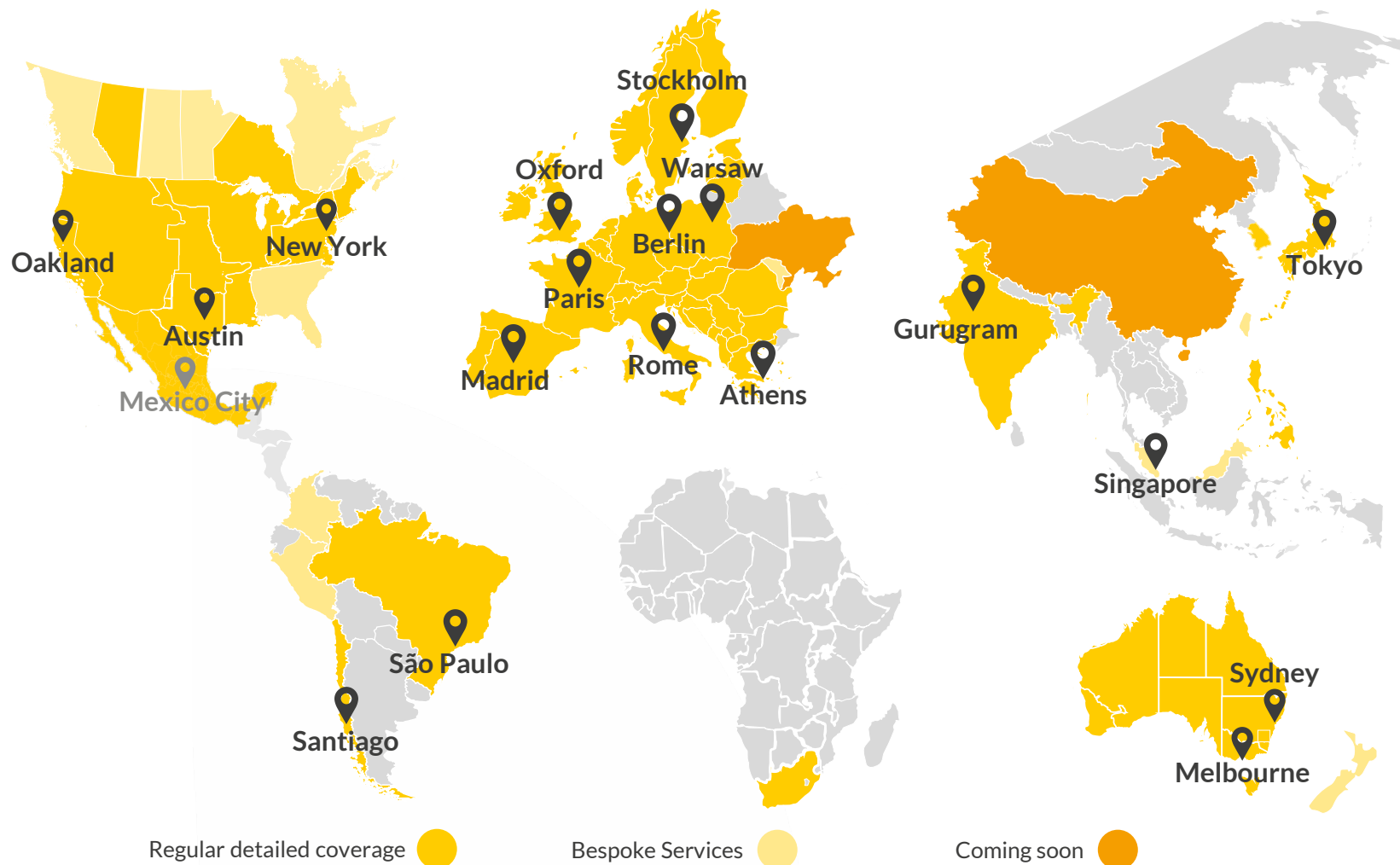
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Transactions
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*Map not to scale

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Thomas Fureder, Managing Director, Barclays



Power & utilities



Oil & gas



Energy consumers



Project developers



Financial sector & investors



Policy & regulation



Agenda

I. Introduction to Aurora

II. Act I: The Success Story

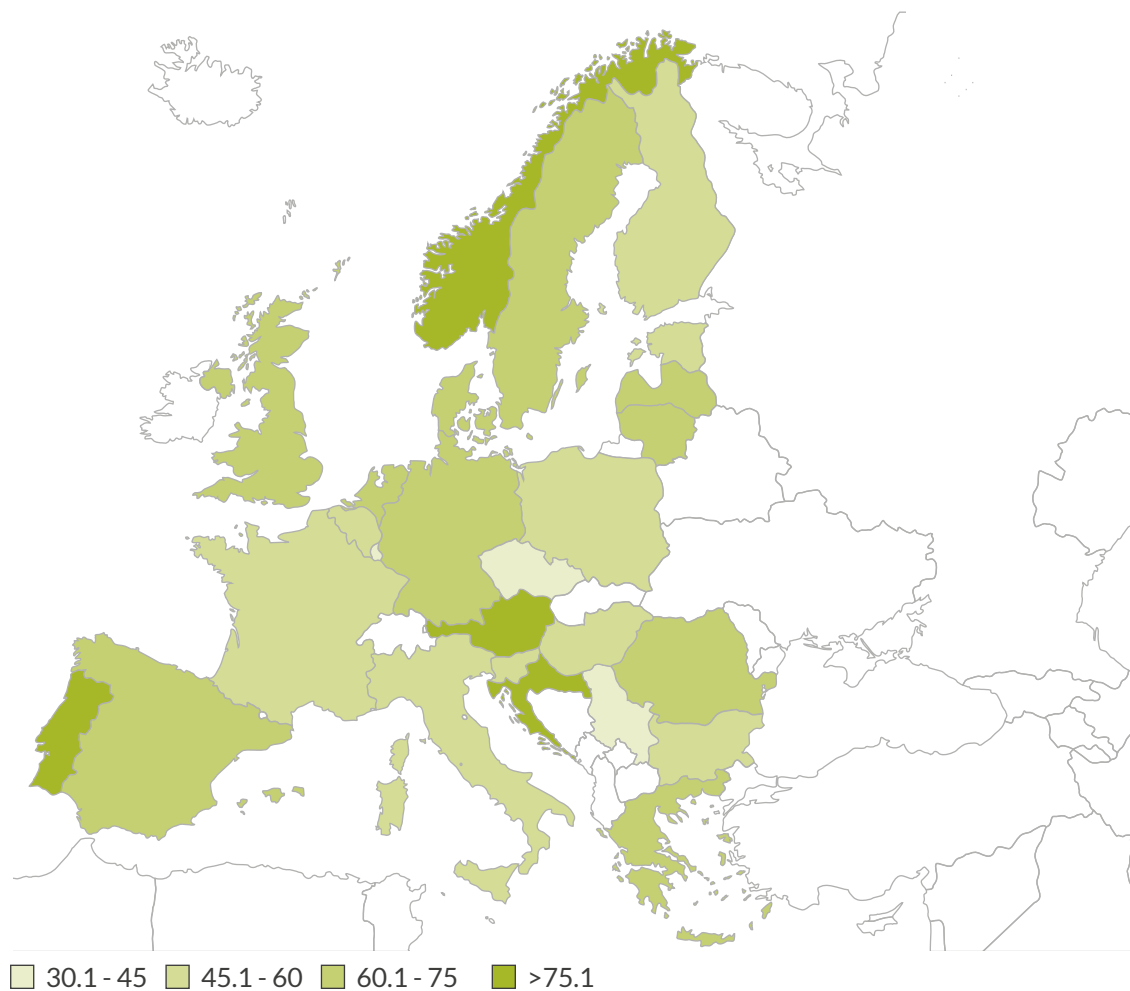
III. Act II: The Challenges

IV. Act III: What Comes Next

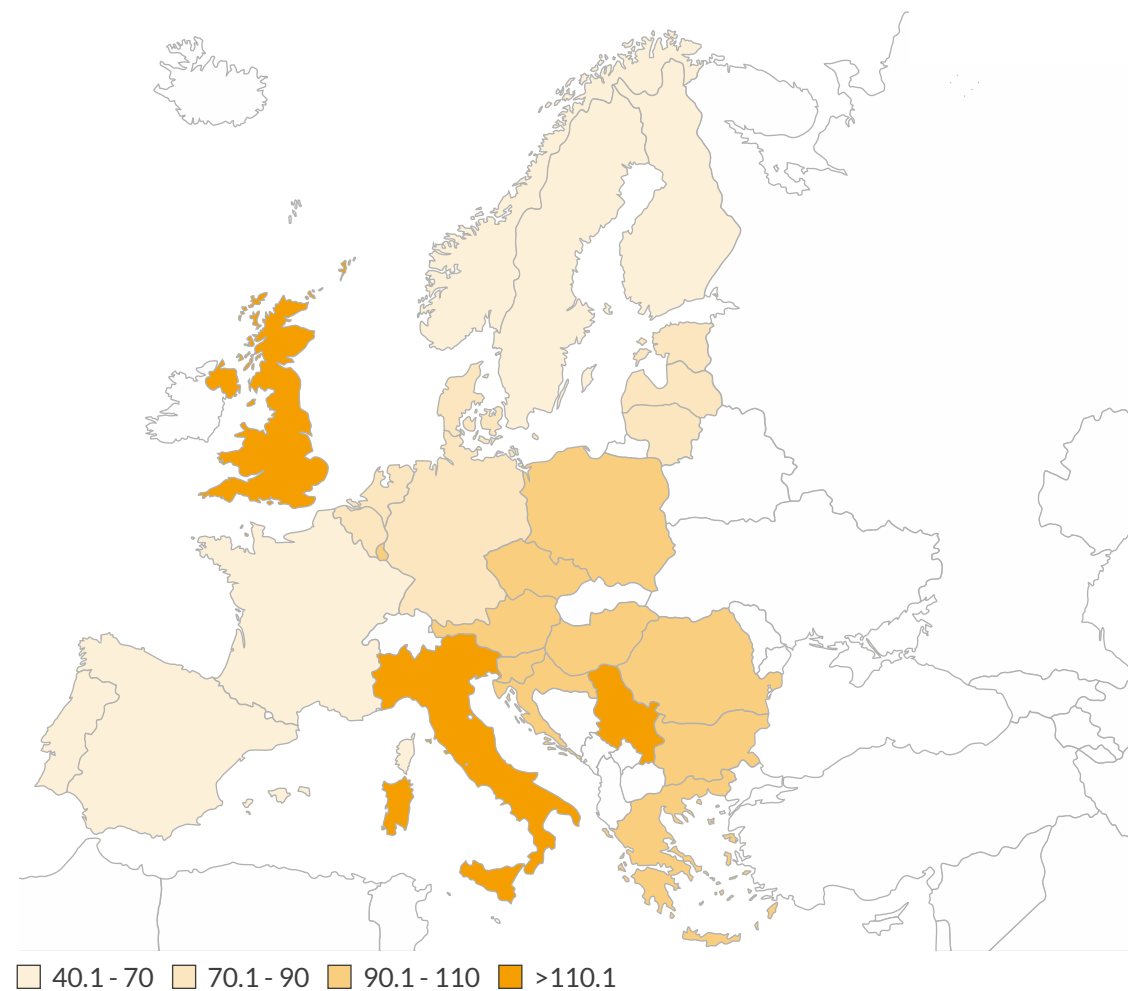
The Iberian power system demonstrates how high renewable penetration can drive lower wholesale power prices

A U R  R A

Share of renewables by country
%



Average wholesale power prices in 2025 by country
€ (real 2025)



Agenda

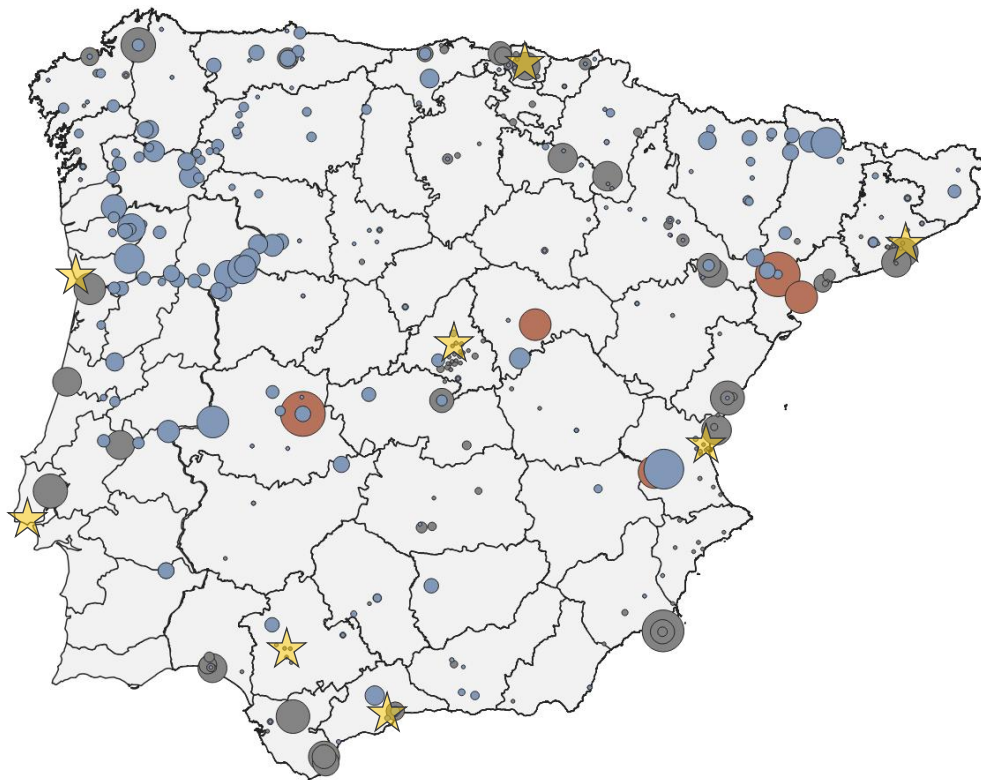
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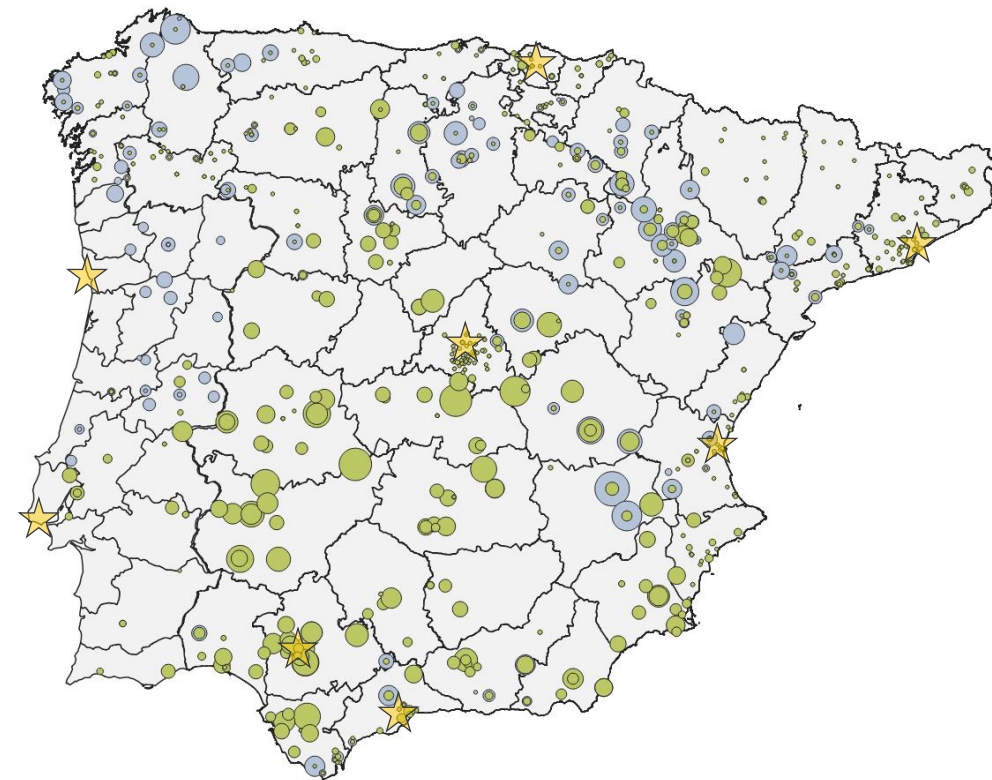
The challenge: the Iberian electricity system is undergoing a paradigm shift from large synchronous generation to small distributed generators



The conventional power system

- A small number of **large synchronous** generators
- System services were an **implicit byproduct**

● Hydro ● CCGT ● Nuclear ★ Biggest Cities in Iberia³



The high-renewables power system

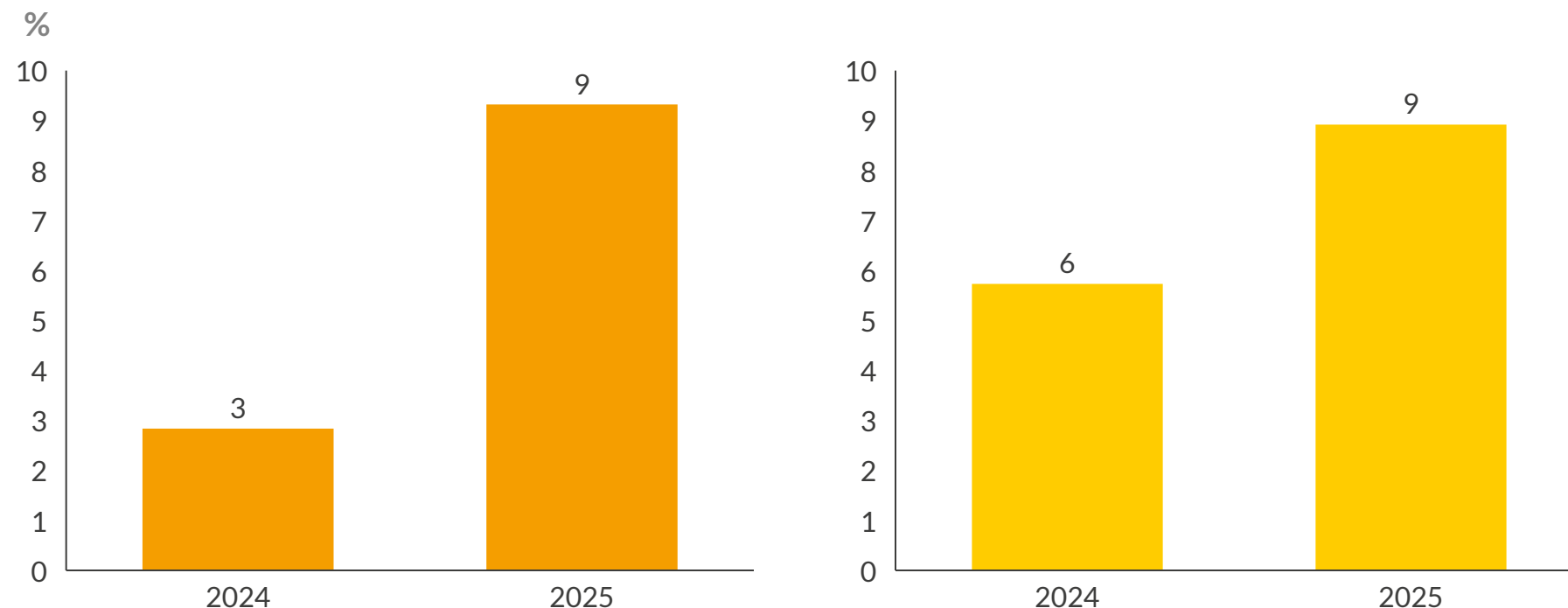
- Hundreds of **small converted-based** generators
- **Location dependent** on resource availability
- Require **incentive** to provide system services

● Solar ● Wind

1) Installed capacity as of 2026 in Spain and as of 2025 in Portugal. 2) Portugal's installed capacity includes transmission-connected assets only and excludes distribution-connected assets, in line with REN data. 3) Largest Cities in Iberia by Population

The challenge: the growth of renewables in Iberia is leading to increased curtailment rates across Spain and Portugal

Grid curtailment rate¹



Total Yearly Generation

TWh

46 TWh

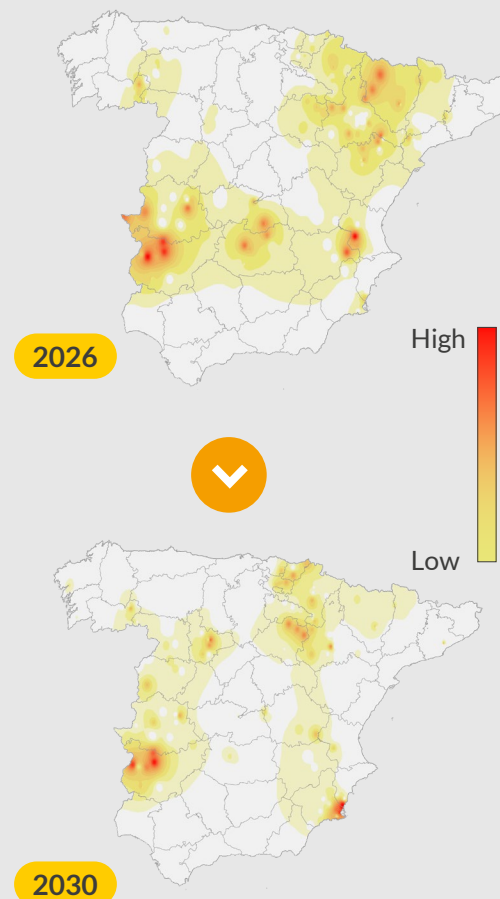
49 TWh

250 TWh

259 TWh



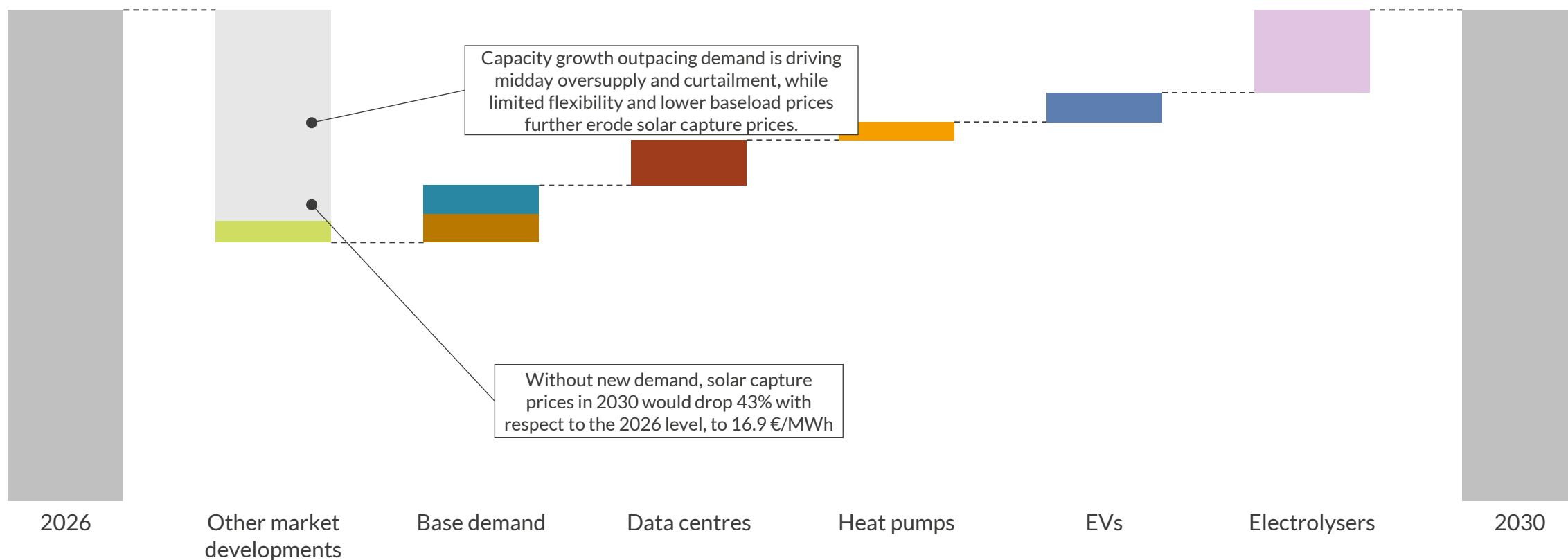
Renewables grid curtailment rate



1) Volumes are sourced from EOS Explorer and REN (using downward PDBF and PDVD volumes).

The challenge: without new electricity demand, Iberian's solar economics would deteriorate materially by 2030

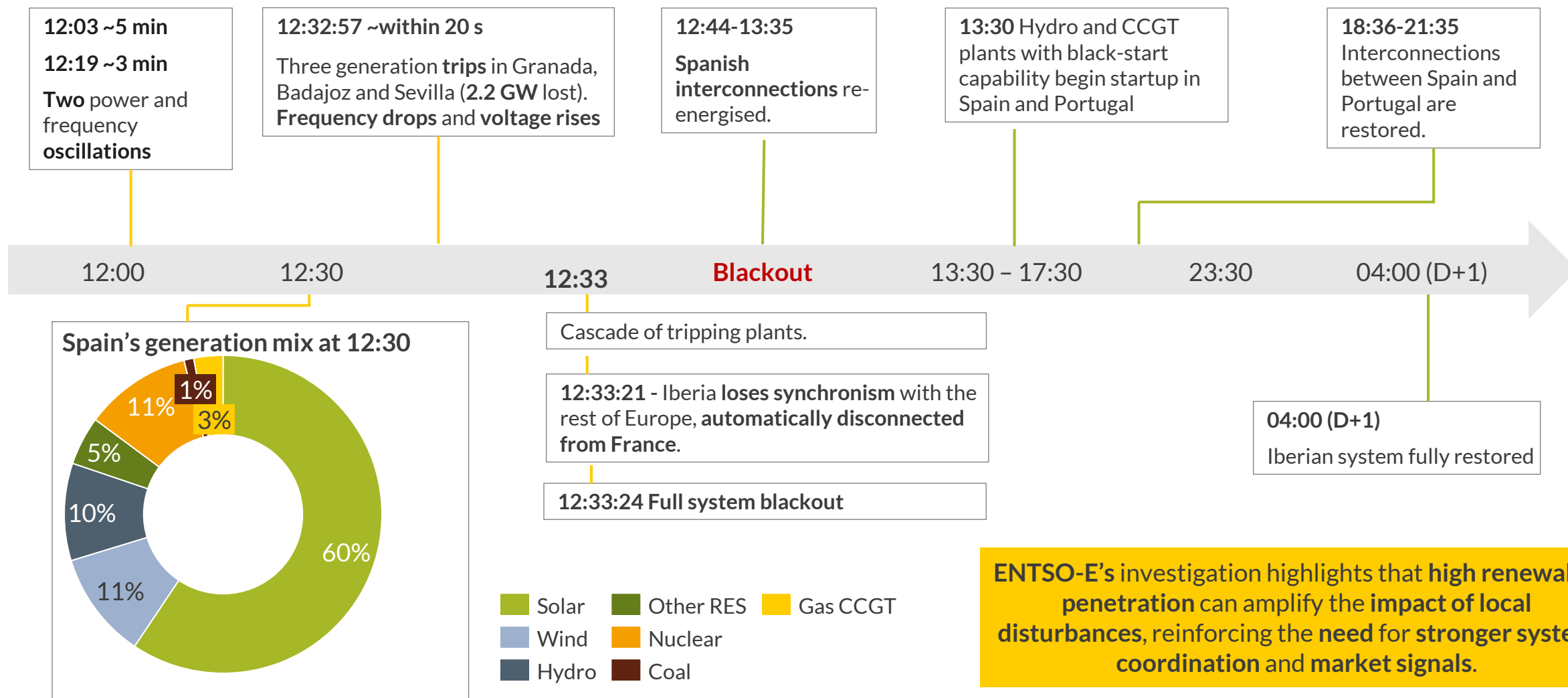
Iberian weighted average demand Solar PV uncurtailed capture price¹ by component
€/MWh (real 2025) - Redacted



■ Industry ■ Other base demand ■ Data centres ■ Heat pumps² ■ Electric Vehicles ■ Electrolysers ■ Other market developments ■ Solar - BtM³ ■ 2030 Price

1) Based on Q2 2026 scenario analysis and Q4 2026 2030 capture prices in the Central scenario. 2) Consumption in residential and commercial sectors; industrial heat pumps are included in industrial demand. 3) Behind-the-Meter.

The challenge: the Iberian blackout showcases the difficulty of operating a high renewables system



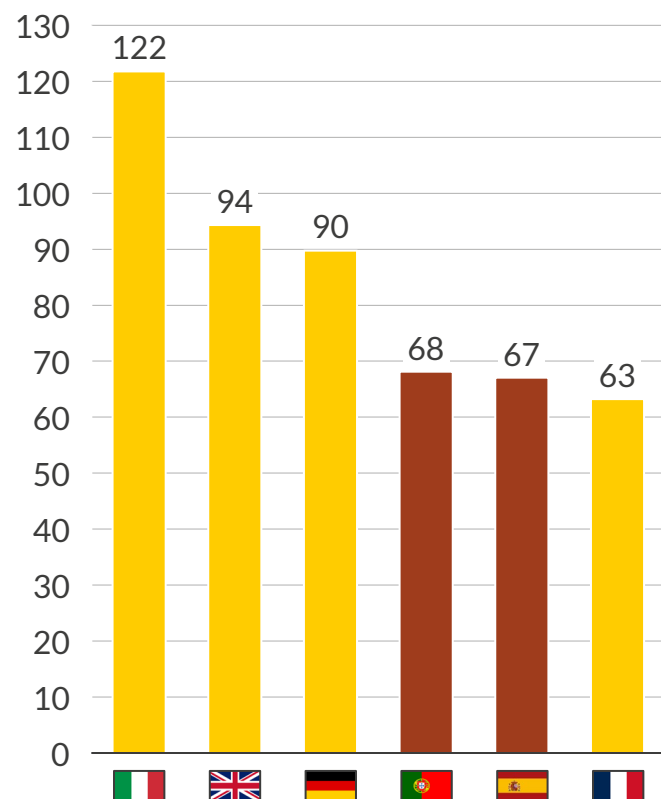
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While wholesale power prices remain low, Iberia needs to address key technical and economic barriers to stimulate demand growth

Iberian wholesale electricity prices are among the lowest in Europe

Average Day-Ahead price in 2025¹
€/MWh (nominal)



However, both markets face three critical technical and economic barriers that need to be addressed to attract demand



Technical barriers

- 1 Regulatory roadblocks**
Slow permitting in both countries and heavily oversubscribed grid connections leave reserved capacity unbuilt and demand unconnected, constraining the conversion of available capacity into actual power offtake.²
- 2 Physical grid constraints**
Limited demand access capacity, a geographic mismatch of generation and demand, and congestion on internal and PT-ES cross-border lines mean cheap power cannot always reach demand, capping electrification and raising prices.



Economic barriers

- 3 Power bill structure and non-wholesale cost drivers**
Both countries' bill structures disincentivise consumption during low-price hours. Together with relatively low CO₂ compensation (weaker in Portugal³) and high operational costs from Technical Restrictions (REE/REN), this erodes the advantage of cheap wholesale electricity.

1) Calculated by averaging the monthly prices for each country. 2) Unused reserved capacity remains a key issue in Portugal, while Spain's permitting process is further complicated by the involvement of both MITECO and regional authorities. 3) Indirect CO₂ cost compensation for energy-intensive industry is more established in Spain, when Portugal's scheme is smaller and less mature, so this barrier bites harder for Portuguese offtakers.

Services that were once implicit are becoming increasingly critical, with system security shifting from assumption to intentional design. A U R R A



Constraints management¹

When **scheduled flows** exceed what the grid can physically carry, the TSO **redispatches**, curtailing generation in congested areas and ramping up costlier plants elsewhere to keep supply and demand balanced



Voltage control

What is it?

Voltage is the electrical potential that drives power through the network; it varies by node

Why existing markets struggle to value it?

Managed through reactive power per location, its value cannot be captured through a single system-wide price



Inertia

What is it?

Inertia is the system's ability to **resist sudden frequency deviations**

Why existing markets struggle to value it?

Procured as a **physical property, not as dispatchable output**



Fast Frequency Response

What is it?

FFR consists of a **rapid power change** that arrests frequency before it moves too far from its target value

Why existing markets struggle to value it?

Currently not remunerated; without explicit pricing, assets are not incentivised to provide it

1) In Spain, the Technical Restrictions market.

System services in Iberia remain largely a grid connection obligation rather than an investable revenue stream, unlike other countries in Europe

			 
 Voltage control	- First tender by 50Hz in 2025 with zonal, region specific tenders. - Standardised products for energy and capacity enhance procurement visibility, offering contracts up to 5 years.	- Voltage Pathfinders and Reactive Power Market tenders (2026) introduce mandatory and optional services with locational procurement targets. - Indexed energy¹, capacity, and energy remuneration² is awarded through pay-as-bid contracts with tenors of up to 15 years.	- Baseline voltage control is mandatory in both countries⁴. Spain will add voluntary real-time and day-ahead zonal products, while Portugal has no equivalent market yet. - No compensation for mandatory provision. Spain will add fixed energy payments (real-time) and pay-as-bid capacity payments (day-ahead), all settled hourly.
 Inertia	- First German TSO tender launched in 2026 with TSO-specific procurement targets. - Fixed €/MW remuneration set by TSO for upward and downward products, with contracts of 2-10 years.	- Stability Pathfinder and Stability Markets³ provide targeted procurement volumes. - Pay-as-bid remuneration for contract availability and delivery services. - Contract durations range from 1 year to >10 years, depending on the product. Except for pathfinders which are multiyear.	Not explicitly remunerated by the TSO.
 Fast Frequency Response	- Cross-border FCR procurement across 9 European countries using a common merit-order platform. - Pay-as-clear availability payments, with daily auctions for 4-hour contracts.	- Dynamic services (Containment, Moderation and Regulation) are procured through daily auctions. - Pay-as-clear availability payments for asymmetric products, with next-day 4-hour contracts.	- Named as primary reserve and defined by ENTSOE's guideline. - Mandatory participation without compensation.

1) Mandatory. 2) Optional and Reactive power markets. 3) Stability Pathfinder rollout was in 2023 and Stability markets rollout was in Y-1 from 2024, Y-4 from 2025. 4) In Spain, a minimum reactive capability is a grid-connection requirement under PO 7.4, and missing it is penalised (€1/Mvarh). In Portugal, REN sends voltage targets to generators with voltage control obligations.

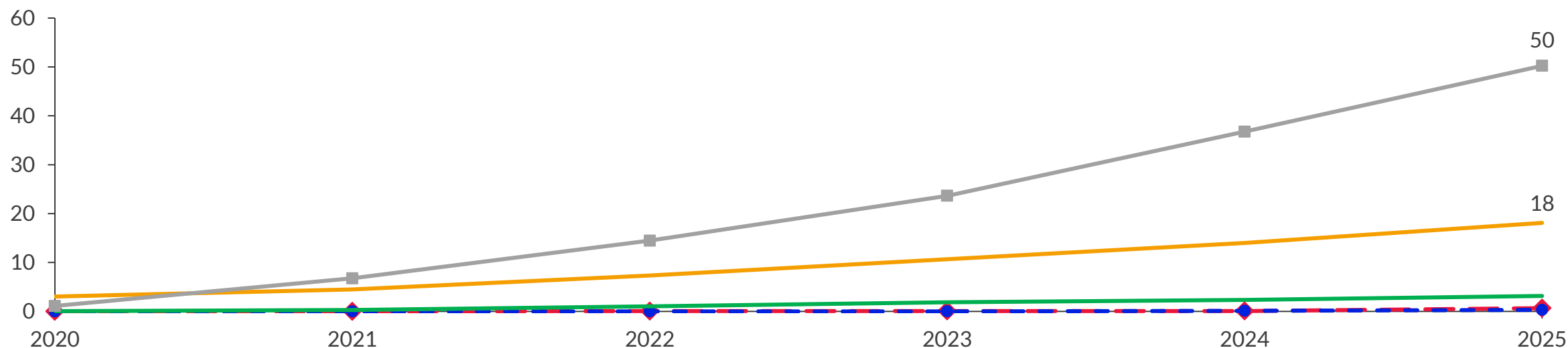
Sources: Aurora Energy Research, Bundesnetzagentur, Blindleister, NESO, CNMC, ERSE.

California's battery boom highlights the untapped potential in Iberia, where deployment remains constrained by policy and economic barriers

Battery capacity expanded rapidly in California and Great Britain, but deployment across the rest of Europe has been slower over the last five years due to less supportive economic and regulatory frameworks.

Installed battery power as % of average system demand¹

%



Grid Connection



Grid connection constraints slowed battery deployment, with lengthy permitting processes, limited available capacity, and unbuilt grid capacity preventing new projects from connecting.

Revenue Stacking



Limited and uncertain revenue stacking opportunities have made battery business cases more difficult to finance and develop.

CM Legislation



Uncertainty around capacity market revenues has hindered battery deployment, as it reduces revenue visibility and increases the risk of battery investment.

— Great Britain — ♦ — Spain — ● — Portugal — — France — ■ — California

1) Calculated as the Installed Capacity in GW over the average GW demand (TWh of annual demand/8.760). Iberian values for Portugal and Spain reflect peninsular (mainland) values only. 2) Relative Difference Between Spain and California (2025)

Greater alignment of regulatory frameworks and charging mechanisms across Iberia would reduce uncertainty and strengthen investment appeal

Where Portugal and Spain are aligned

Where Portugal and Spain differ

Single day-ahead spot market

Portugal & Spain share MIBEL¹, managed by OMIE² since 2007. Pay-as-clear, 15-minute³ and EU-coupled since 2014.

Forward & futures market

Shared forward market run by OMIP⁴ and futures on EEX⁵, complemented by bilateral/OTC⁶ contracts.

Liberalised, unbundled model

Both markets are liberalised, unbundled and privatized, whereas end-consumers are free to choose their supplier.

Renewable generation mix

Both systems are dominated by renewables with large hydro fleets. Only difference relies on nuclear capacity siting in Spain.

Isolation from Europe

Despite its interconnection with France, Iberia remains weakly connected to the rest of, while maintaining strong internal integration between Spain and Portugal.

Two national TSOs

Identical role, separate operators: REE⁷ in Spain and REN⁸ in Portugal.

Capacity Mechanisms

Spain and Portugal are pursuing separate capacity-mechanism designs and timelines rather than a coordinated Iberian scheme.

Network charges

Similar system costs recovered differently. Access tolls & charges (ES⁹) vs the TUGS¹⁰ (PT¹¹). The IVPEE¹² applies only in Spain, and BESS¹³ tariff exemptions differ.

Green certificates

Guarantee-of-origin / green-certificate frameworks are run separately, with different rules across the two markets.

Permitting & grid access

Spain offers a streamlined co-location access-permit shortcut¹⁴, and Portugal manages hybridisation via TRC amendment and capacity allocation, with fewer administrative advantages.

Uncoordinated AS¹⁵ design

AS have been reformed independently, with Portugal adding bmFRR¹⁶ and long-term auctions ahead of EU¹⁷ platform adhesion, and Spain retaining its own technical-restrictions/AS design, so products are not harmonised across the border.

Key Takeaways

- 1** **Iberia has won the first half of the energy transition.** Renewables supply a larger share of electricity demand and wholesale prices are some of the lowest in Western Europe.
- 2** Cheap power only creates value if the grid can deliver it to consumers and it keeps driving electrification. **Without new demand, Iberian solar capture prices fall 43% by 2030**, while curtailment keeps climbing.
- 3** **The 28 April blackout showed what changes when synchronous plant steps back.** Voltage control, inertia and fast frequency response used to be a by product of how the system was built. **Economic signals are necessary to ensure the system continues to have enough of them.**
- 4** **Battery deployment in Iberia has stalled** despite the clear need. **Connection challenges, regulatory uncertainty** and an **undeveloped revenue stack have held it back**, hurdles California has shown can be overcome.
- 5** **Iberia has a fully integrated day ahead power market**, but as revenues and decisions start to become more complex, **aligning capacity mechanisms, network charges and system service products across Spain and Portugal is needed** to keep a fully integrated market and reap the benefits of it.

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