Teneo

Spanish Lessons in the Dark: Implications of the Iberian Outage for Energy Planners and Investors

Teneo Insights | May 2025

On April 28th, Spain, Portugal and parts of southern France experienced one of the largest power outages in European history. The blackout lasted over 10 hours in many areas, affecting approximately 60 million people, resulting in nine fatalities and causing an estimated €2B-5B in economic loss.[1]

To the credit of Red Eléctrica de España (REE), the power was restored to the majority of customers within two hours and 99% of the power was back on within 16 hours. The specific causes (likely more than one) of the outage remain under intense investigation, though several potential causes mentioned immediately following the event – including cyber or physical attack and extreme (terrestrial or solar) weather – have been dismissed.[2]

Regardless of the specific sequence of events leading to the outage, several factors greatly increased the risk of such a catastrophic event occurring, including structural weaknesses of the Iberian grid, market design, technology gaps and planning/operational issues. We believe the lessons from these system

---

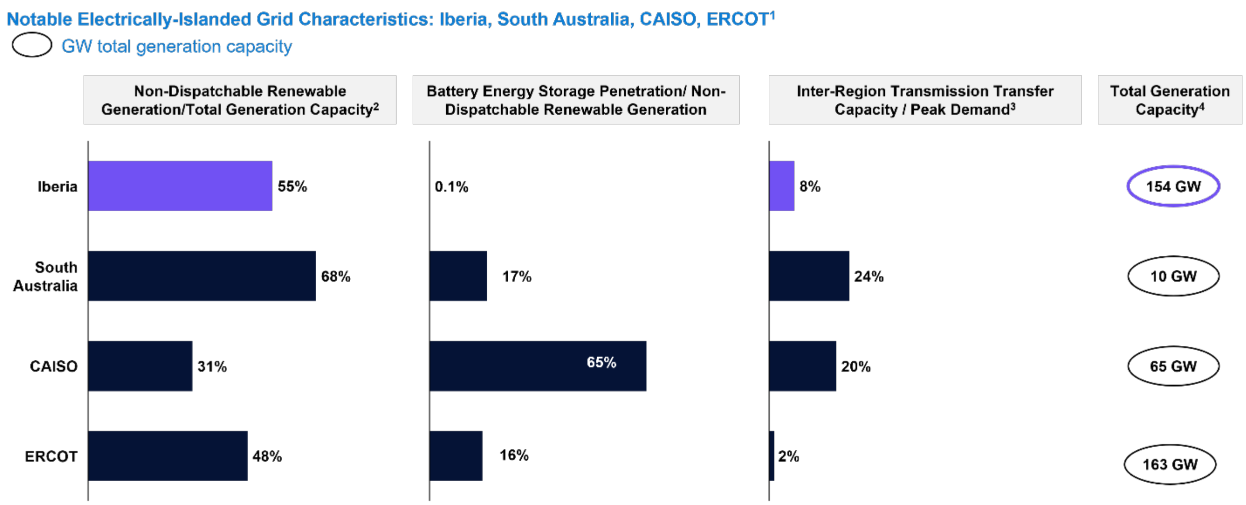
[1] Per investment bank RBC via Reuters on April 29, 2025 (link); Anadolu Ajansi, April 30, 2025 (link)
[2] World Economic Forum, May 1, 2025 (link); Euro News, April 29, 2025 (link)

interactions are relevant to the high renewable penetration grids, including ERCOT in Texas, CAISO in California and Southern Australia, as well as many other regions worldwide.

Designing to ensure reliability in renewables-heavy grids

Commentators have consistently identified a key underlying cause of Iberian grid fragility as insufficient interconnection with the broader European network, particularly in light of the region's heavy reliance on intermittent energy sources. While this is now (partially) being addressed by the Bay of Biscay transmission line, system interconnection transfer capacity via high voltage transmission to the rest of the European grid is less than 10% of the region's generation capacity. This is notably lower than the EU's 2030 target of 15% as well as many other islanded electric grids with high renewables penetration (see Figure 1 below).

Figure 1: Comparison of Iberian with Other Isolated Power Systems



Source(s): Teneo research and analysis; ERCOT (Snapshot Comptroller 2023; Pablo Vegas's Presentation to US House of Reps. Subcommittee on Energy on March 25, 2025); CAISO (2025 Summer Loads and Resources Assessment May 2025 & 2024, CAISO Key Statistics December 2024, FERC Docket AD 10-02-006 Informational Filing for CAISO Corp); CEC (Storage Survey accessed on May 12, 2025, CEC Docket 22-IEPR-03 Electricity Forecast 12/16/2022); Red Electrica (National Electricity System Installed Capacity accessed May 12, 2025, Maximum Instantaneous Capacity via ree.es); REN (REN Datahub: Monthly Electricity Consumption); Associacao de Energias Renovaveis (Renewable Electricity in Review 2024); Rabobank (Backup Power for Europe Part 4: Spain's BESS Market Is Heating Up); AEMO (Southern Australia Electricity Report 2024)
Note(s): 1. Figures above based on publicly-available sources with different dates referencing generation installed capacities between 2023 and 2025 and demand peaks that occurred between 2007 and 2025; 2. Includes solar PV, wind, 3. Inter-country or regional transmission capacity over peak demand (10.4 GW in CAISO as maximum import capability less ETC and TOR, Combined Spain and Portugal peak despite occurring on different days: 45.5GW in Spain in Winder 2007 and 9.89 GW in Portugal in Jan 2021, 3.6 GW in South Australia in December 2024, 85.5 GW in ERCOT in April 2023); 4. Excludes energy storage (pumped, thermal, battery), used as denominator of the % penetration and interconnection ratio analysis

Even without sufficient interconnection capacity, the system was able to accommodate heavy reliance (60% and above) on intermittent photovoltaic (PV) and wind generation without incident. It did so through a combination of the regional grid's mesh design and the integration of dispatchable nuclear, hydro and pumped storage generation. Unlike other systems featuring high renewables penetration, this was accomplished with limited reliance on curtailing PV or wind production. Unfortunately, on April 28th, several critical units of dispatchable nuclear generation[3] were offline due to lower energy prices, while a significant portion of hydro capacity was offline for planned maintenance, further increasing the risk of a major outage.

The ensuing outage that befell the Iberian grid reveals its vulnerability to extremely rapid and complex changes to system load and generation. The decline in system inertia – resulting from the replacement of fossil generation with inverter-based renewables – combined with increasingly intense and unpredictable fluctuations in demand, necessitates the ability to optimize grid operation at the sub-second level.

In the case of Iberia, the key missing components to enable rapid intervention, possibly avoiding the outage, were likely a) the lack of appropriate grid technology, such as grid-forming inverters and synchronous condensers and b) inadequate battery energy storage system (BESS) capacity. While the former set of technologies is still in the early stages of adoption – making their absence in Iberia unsurprising – the limited deployment of BESS is more notable, particularly when compared to other renewables-rich systems like California and Texas in the U.S. (see Figure 1).

We hypothesize that the surprisingly low installed BESS capacity reflects shortcomings in market design, which result in inadequate revenue streams available to support potential BESS projects. There is insufficient direct remuneration for very rapid (and accurate) frequency regulation resources that BESS is ideally suited to provide, widely used in the U.S. and elsewhere.[4] Similarly, there is no direct remuneration for inertia, such as market-based products already offered in the UK and Australia. Unlike many other electricity markets, there is an absence of granular energy prices (i.e., 15-minute versus hourly prices) that would provide a more lucrative energy arbitrage revenue stream for BESS. Currently, there is no capacity or capacity-like products that would support the presence of BESS in the market, though they are planned. And finally, there is a failure to sufficiently overcome administrative barriers to rapid connection and participation of BESS in the wholesale market.

Beyond transmission investment, changes to system standards and operations, and the reform of market design mentioned above, we see several additional opportunities to improve the reliability and affordability of systems like Iberia's around the world.

- **Next generation grid architectures and technologies** – including mini/micro-grids, sensors, advanced analytics, edge computing – provide valuable insurance in the event of delays to major infrastructure improvements (e.g., high-voltage interconnects) and market reforms. Utilities need to communicate the benefits of earlier investment in these technologies on the basis of minimizing total expected costs to their customers (including from outages). Old-fashioned, deterministic cost avoidance is penny wise and pound foolish.
- **BESS and other forms of energy** storage can provide extremely beneficial, economical sources of reliability, but require thoughtful market design to take off.
- Further development of **behind the meter BESS and demand management**, seamlessly integrated into the grid for maximum responsiveness, and fairly compensated for the full range of grid services it provides. This offers extra reliability for customers willing to pay a premium for it, as well as significantly increasing grid resilience.

[3] Nuclear units Almarez 1 & 2, plus the Cofrentes plant
[4] Other forms of energy storage which are better represented in Iberia, including pumped storage and thermal energy storage (often accompanying Concentrated Solar Power units), are less able to provide frequency regulation services with high accuracy and with extremely short delays.

Authors

Dan Gabaldon
Vice Chair, Management Consulting and Head of Energy, Teneo

Robert Zabors
Vice Chairman, Management Consulting and Head of Infrastructure, Teneo

Omar Saadeh
Senior Director, Teneo

Kyle Datta
Head of Climate Strategy, Coopersmith Law & Strategy

The Global CEO Advisory Firm

Teneo is the global CEO advisory firm.

We partner with our clients globally to do great things for a better future.

Drawing upon our global team and expansive network of senior advisors, we provide advisory services across our five business segments on a stand-alone or fully integrated basis to help our clients solve complex business challenges. Our clients include a significant number of the Fortune 100 and FTSE 100, as well as other corporations, financial institutions and organizations.

Our full range of advisory services includes strategic communications, investor relations, financial transactions and restructuring, management consulting, physical and cyber risk, organizational design, board and executive search, geopolitics and government affairs, corporate governance and ESG.

The firm has more than 1,600 employees located in 40+ offices around the world.

teneo.com