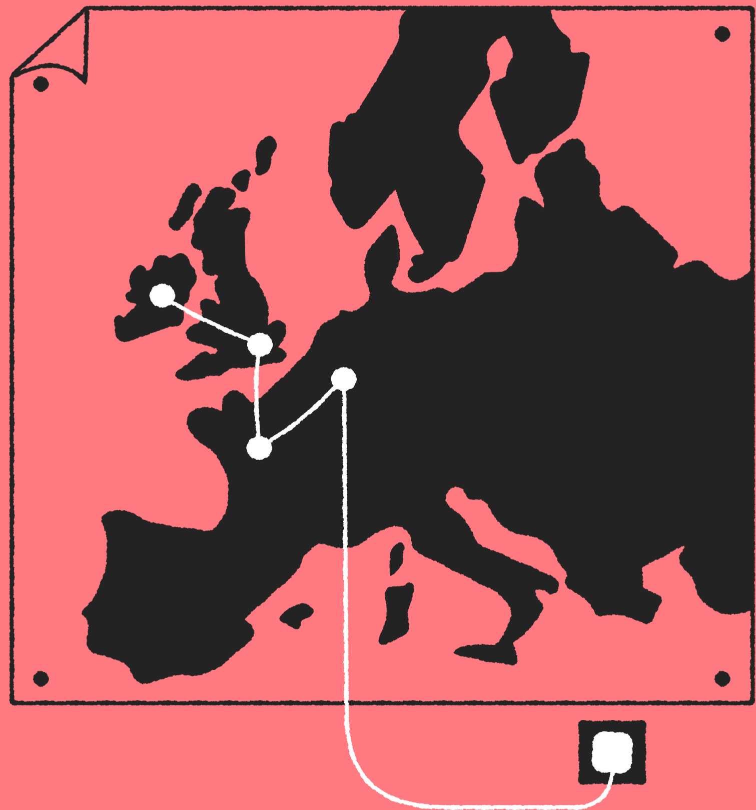
February 2026

Infrastructure for Energy Resilience: An investable system of assets and services



A White Paper by Worthwhile Capital Partners and Foresight Group.

Foresight
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"The grid is the foundation of the transition to reliable clean energy, but its role has been held back by a regulatory fixation on minimising costs instead of maximising the new opportunities that strong and intelligent networks could unleash.

Dr Peter Wall
Head of Grids Research, BloombergNEF

Executive Summary

The European energy transition stands at a critical juncture. Over the past decade, policymakers and investors alike have been focused on scaling renewables generation. The results have been impressive: Europe is a leader in wind and solar deployment, with several countries now sourcing more than 50% of their electricity from renewable sources during peak months. (Source: IEA, Portugal; IEA, Denmark)

But the next phase of the transition demands a new priority: economic resilience away from government subsidies, and the geopolitical objective of energy independence.

The April 2025 blackout in Spain served as a reminder of the importance of energy systems resilience. Despite having tripled its solar capacity in just five years, the country experienced a near-total power system failure. Importantly, the blackout was not caused by renewables themselves, but by the system's inability to integrate them at scale and Spain's structural isolation from the rest of Europe's electricity system.

The lesson is neither uniquely Spanish nor isolated. Across Europe, from the congested northern wind corridors of Sweden to the heat-stressed substations of Italy and the under-connected Iberian Peninsula, rapid renewable growth is exposing critical opportunities to modernise and reinforce the grid.

This paper argues that, for investors, resilience is not merely a policy issue; it is a defining investment theme. The next generation of infrastructure capital must focus not only on generating clean electrons, but also on ensuring those electrons flow, balance, and stabilise the system. That means prioritising technologies and strategies such as grid-scale storage, interconnection, system balancing assets, and digital grid orchestration.

The case for resilience is not just risk mitigation. It is an opportunity to earn returns by solving real, growing, and structurally under-addressed challenges at the heart of Europe's energy future.

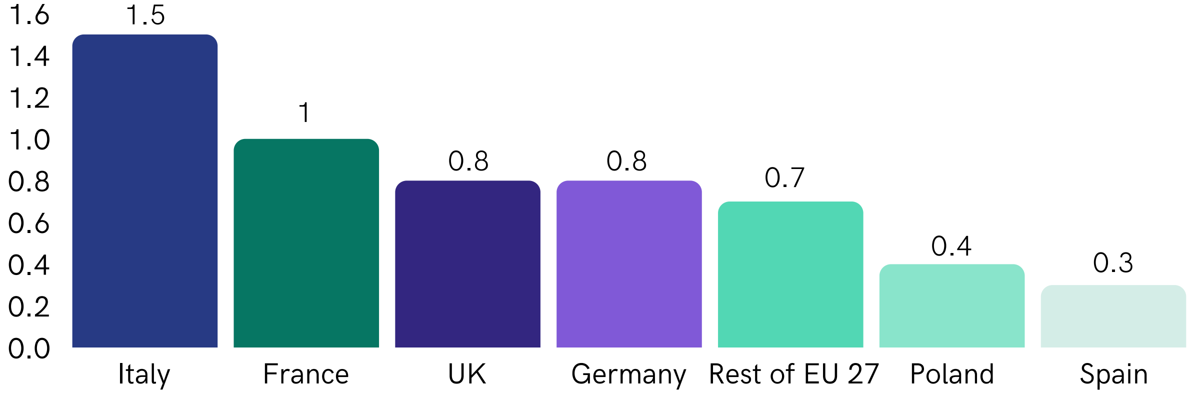
For investors, looking beyond the intricacies of the energy transition, real assets are set to grow in demand as the world enters an era of greater volatility and inflation risk. For investors, this shift offers a chance to diversify beyond renewable generation into infrastructure assets like grids and storage, which can enhance portfolio stability through low or negative correlation.

1. The Spanish Blackout: when abundance becomes instability

In April 2025, Spain, one of Europe's solar leaders, suffered a nationwide power outage that affected over 10 million homes. The crisis unfolded over several hours as solar generation spiked and grid voltage destabilised due to a lack of control resources and low grid strength being compounded by transmission bottlenecks.

At the heart of the issue was a stark imbalance between renewable investment and grid infrastructure. Spain invested just €0.30 in grid modernisation for every €1 spent on renewables between 2020 and 2024 (See Figure 1 below). (Source: BloombergNEF). BloombergNEF's New Energy Outlook modeling indicates that this ratio must exceed €0.8 out to 2030 to deliver an economic transition for Europe. Spain's interconnector capacity, a critical buffer during periods of stress, stood at just 6% of generating capacity, well below the EU's 15% target for 2030. Development of grid-enhancing technologies – quick-to-deploy solutions that enhance the capacity of the existing grid – has been slow too. The Spanish peninsular grid has no operational synchronous compensators – devices that can provide dynamic voltage control and inertia without fossil fuels. (Source: Ember Energy).

Figure 1. Grid to renewable energy investment ratio, 2020-24[1]



The blackout was the culmination of long-standing systemic issues that had already been creating hidden challenges and costs for years. Spanish taxpayers had been bearing the burden well before the blackout: in 2024 alone, Spain paid over €3 billion to gas power plants to address non-frequency stability problems, up sharply from €0.8 billion in 2020 (Source: BloombergNEF). Moreover, regulation enabling PV systems to support grid voltage was delayed for five years and only approved weeks after the blackout.

In short, while solar capacity soared, the grid remained fundamentally 20th-century in design: centralised, inflexible, and poorly interconnected. (Source: Bloomberg Green podcast, July 2025 – Zero: The Climate Race).

Spain's blackout illustrates the need for investment in renewable-enabling infrastructure.

[1] BNEF (2025), Spain's Blackout a Costly Lesson on Grid Strength.

2. Technologies Enabling Resilience: Infrastructure beyond generation

As the energy transition progresses from theory to reality, the limitations of a generation-centric approach are becoming ever more apparent. While the rapid deployment of solar and wind has reshaped the European power mix, it has also revealed a critical shortfall: the shortage of supporting infrastructure capable of absorbing, transporting, storing and stabilising the flow of renewable electricity. This is the crux of the resilience challenge, and the defining opportunity for infrastructure investors.

The next wave of investment is no longer about simply building evermore power generation infrastructure. It is about enabling what has already been built to function dependably. This requires a layered architecture of technologies that, together, provide the flexibility, stability, and interoperability a low-carbon power system demands. Among these, four stand out as foundational pillars: grid-scale storage, interconnectors, synchronous condensers, and grid-forming inverters.

2.1 Grid-Scale Storage: Bridging the gap between supply and demand

Of all emerging grid technologies, battery energy storage systems (BESS) have advanced the furthest in both technical maturity and commercial uptake. Their growth reflects complementary trends: significant cost reductions in wind and solar have made renewable generation highly competitive, and BESS enables this power to be time-shifted and dispatched as needed for system reliability. This combination supports optimal integration of variable resources into the grid.

In addition to energy shifting and arbitrage, modern grid-scale batteries provide services such as frequency stabilisation, reactive power support, and congestion management. These capabilities position storage as an important flexibility and resilience resource within the evolving power system.

The market response has been swift. Europe’s installed BESS capacity stood at roughly 10.3GW at the end of 2024 and is expected to expand fivefold by 2030. (Source: Aurora Energy Research). Countries such as Italy, the UK, and Germany are leading this surge, not just due to their renewable penetration, but because of their evolving market designs that allow batteries to earn revenue across multiple value streams. In the UK, for example, dynamic containment and frequency response markets have become primary revenue anchors, while in Italy, batteries are now being procured to replace retiring thermal plants under capacity support schemes. (Source: Aurora Energy Research – 2024 European BESS Outlook)

For investors, BESS now offers a combination of short-duration volatility capture and long-duration system value. And in the wake of events like the Spanish blackout, their role in absorbing production surges and preventing frequency collapse has become imperative.

2.2 Interconnectors: Geography as a resilience strategy

While storage solves the problem of time, interconnectors solve the problem of place. They are the physical manifestation of a grid's ability to share, balance, and protect itself through regional cooperation.

55% of Europe's power system have limited electricity import options, substantially increasing the risk of blackouts - with Spain, Ireland, and Finland being particularly vulnerable to said blackouts (Source: New lines of defence: how interconnectors keep the lights on | Ember). Spain's limited interconnection with France was a direct contributor to the 2025 blackout. With just 3-4% interconnection relative to generation capacity, well below the EU's 15% target, the country was unable to export excess solar or import balancing power. (Source: ENTSO-E Long Term Network Development Study 2024). The result was a cascading system failure triggered by an imbalance that could have been absorbed by a more robustly connected grid.

In the Nordic region, the focus is on the ongoing development of internal grid capacity. Sweden, for example, is well connected to its neighbours through interconnectors, but large wind resources in the northern SE1 and SE2 zones are not always fully utilised due to limited transfer capacity to southern demand centres (SE3 and SE4). To address this, Svenska kraftnät has a multi-year grid expansion programme underway, with major projects delivered over a 5-10 year horizon.

From an investment standpoint, interconnectors offer long-duration often regulated returns, backed by national or supranational support frameworks such as the EU's Trans-European Networks for Energy (TEN-E) and REPowerEU funding initiatives. But their significance goes beyond returns. Interconnectors embody a resilience logic: they distribute risk, enable cross-border balancing, and reduce the likelihood that a localised supply-demand mismatch becomes a systemic crisis. From a geopolitical standpoint, interconnectors also provide greater security in times of uncertainty and war. During the most intense attacks on Ukraine's energy infrastructure in 2024 for instance, interconnectors enabled the import of over 800 GWh of electricity per month. (Source: Ember)

2.3 Synchronous Condensers: Rebuilding the physical backbone of grid stability

As fossil fuel power stations are phased out, a less obvious – but no less critical – component of power system stability is being lost: inertia. In traditional grids, inertia is provided by the spinning mass of turbines in coal, gas, and nuclear plants. This rotational energy slows down frequency fluctuations and gives system operators precious seconds to react to disturbances.

The rise of inverter-based renewables has radically reduced inertia. These resources, while clean, are electronically interfaced and do not naturally provide the same stabilising force. The result is a grid that is faster, but also more fragile.

Synchronous condensers restore this lost stability. Essentially spinning machines connected to the grid without producing electricity, they replicate the physical characteristics of thermal generation, delivering inertia, voltage support, and short-circuit strength. Their use is expanding across Europe with 60 new projects in the last 5 years (Source: BloombergNEF).

These assets are often overlooked by investors but they are increasingly mandated by transmission system operators as part of grid compliance and are supported by fixed or availability-based payments. As such, they can resemble regulated utility infrastructure in both risk and return, providing portfolio stability while underpinning the functioning of the broader system (provided regulatory and market frameworks recognise this role).

2.4 Grid-Forming Inverters: The digital core of the post-thermal grid

If synchronous condensers are the analog backbone of resilience, grid-forming inverters are its digital brain. As power systems become dominated by inverter-based resources - batteries, solar, wind - the role of inverters evolves from passive interfaces to active grid stabilisers.

Traditional inverters are "grid-following": they sync to an existing frequency and voltage. But in high-renewables contexts, there may be no stable frequency to follow. Grid-forming inverters resolve this by setting the frequency themselves, providing what engineers call "virtual inertia". They mimic the behavior of a rotating machine, offering fast frequency response, voltage control, and the ability to operate in islanded or black-start conditions.

This is not a future vision. Grid-forming inverters are already being deployed in commercial projects.

Germany is still in the pilot phase, testing inverter-led stabilisation under its System Stability Roadmap. By contrast, the UK and Australia have moved beyond trials - they are already paying grid-forming batteries to deliver essential grid stability services. In Phase 2 of NESO's Stability Pathfinder, 65% of the inertia required was procured from grid-forming battery storage, and Australia now operates over 5 GW of BESS with grid-forming inverters under AEMO's technical standards following multiple successful demonstrations (source: BloombergNEF). Looking ahead, European generator requirements will eventually mandate grid-scale storage to be grid-forming.

For infrastructure investors, the rise of grid-forming technology opens a new chapter. These inverters are programmable, scalable, and increasingly revenue-relevant as system services are unbundled and monetised. Crucially, they enable portfolios that combine BESS and renewables to offer not just energy, but resilience as a theme that is fast gaining traction with Transmission System Operators (TSOs) and regulators across Europe.

3. Monetising Resilience: From system value to revenue stream

If the technologies described above represent the architecture of resilience, then regulation is the operating system. Grid investments are highly exposed to decisions by regulators and system operators, and the monopoly nature of transmission and distribution makes this terrain tricky to navigate without deep expertise. Even small rule changes can reshape outcomes dramatically: In the UK's Stability Pathfinder, Phase 2 rules enabled grid-forming batteries to win 65% of inertia contracts, but a small rule change in Phase 3 cut that to zero.

Infrastructure doesn't become investable simply because it's necessary; it must be made remunerative through stable, predictable frameworks. As Europe's energy transition matures, policy is starting to catch up with system needs, unlocking new monetisation channels for resilience-enhancing technologies. The future of European clean energy policy is increasingly focused on linking clean energy development with competitiveness, security, resilience, and strategic autonomy.

For example, the recent Clean Industrial Deal State Aid Framework (CISAF) allows EU Member States to support investments in clean energy, industrial decarbonisation, and clean tech manufacturing, including grid infrastructure. Another initiative is the European Commission's European Grids Package[2] (formally announced on December 10, 2025) and the new Clean Investment Strategy, both part of the broader Clean Industrial Deal. Pending parliamentary approval, the Grids Package (and Energy Highways initiative) introduce guidance on grid connections, contracts for difference, faster infrastructure planning, and a revision of the TEN-E Regulation for cross-border energy projects. It emphasises the need for private investment to build affordable, resilient energy infrastructure through future-proof network charges, fair cost-sharing, and innovative financing models like bundling PCIs/PMIs. The upcoming Clean Investment Strategy will focus on de-risking private capital and partnering with the European Investment Bank to accelerate grid deployment.

The prevailing sentiment in Europe is that this is the moment: geopolitical and geoeconomic pressures have turned into tailwinds, accelerating reform and investment in Europe's resilience.

[2] https://ec.europa.eu/commission/presscorner/detail/en/ip_25_2945

From Externalities to Markets

Historically, grid stability was treated as a public good, bundled into generation and managed by vertically integrated utilities. Today, in liberalised power markets increasingly dominated by Variable Renewable Energy (VRE) and merchant generation, stability must be priced, procured, and delivered explicitly. This shift is creating new investment opportunities where none existed before.

Several regulatory trends are converging to support this transition:

3.1 Unbundling of System Services

System services such as frequency regulation, inertia provision, voltage support, and black start capability are increasingly treated as standalone, competitively procured products. This shift reflects the growing need to stabilise power systems dominated by inverter-based resources, and creates clearer investment signals for flexibility assets:

- United Kingdom: National Grid ESO's Stability Pathfinder programme has contracted synchronous condensers and battery assets to provide system inertia, short-circuit strength, and voltage control. These services are remunerated through fixed long-term contracts designed to complement energy and capacity markets.
- Germany: While not yet nationwide policy, Germany has begun integrating grid-forming inverter requirements into some battery tenders, especially in grid-constrained areas. Pilot programmes under the System Stability Roadmap-such as the "Netzbooster" initiative and funded trials by TransnetBW and 50Hertz-are testing resilience-enhancing functionality in BESS systems.
- Italy: Since 2022, Italy's capacity market, managed by Terna, has explicitly enabled the participation of energy storage systems, including batteries, as a technology-neutral means of enhancing system adequacy and resilience. These resources receive multi-year availability payments, similar in structure to thermal plants, and are increasingly critical in replacing retiring fossil baseload.

This unbundling reflects a broader trend across Europe: resilience has become an investable service category, no longer bundled into generation or overlooked in market design.

3.2 Grid Modernisation Funding

REPowerEU, the European Commission's €210 billion response to the energy crisis, explicitly identifies grid infrastructure as a strategic investment area. Member states are now able to direct funding toward: (Source: European Commission – REPowerEU Plan)

- Interconnector development
- Battery integration
- Digital grid upgrades
- Inertia and system strength projects

This opens the door for blended finance, where public capital de-risks private investment in resilience-enabling assets. In Portugal and Poland, public-private partnerships are already being explored for BESS and grid reinforcement platforms.

3.3 Grid Modernisation Funding

Several jurisdictions have begun to mandate resilience capabilities in connection agreements. For instance, new BESS projects in parts of Germany, Ireland and Finland must demonstrate grid-forming capabilities to receive grid access. This transforms what was once an optional enhancement into a licence to operate.

From an investment perspective, this shifts the conversation: resilience is no longer a trade-off between optional system value and higher capex. It becomes the precondition for market entry and long-term viability.

4. Aligning Capital With Resilience: Foresight's strategic positioning

At Foresight, we believe that infrastructure for resilience is not merely a sub-theme of the energy transition, but the scaffolding upon which the entire transition relies. This belief is not philosophical. It is embedded in our investment strategy.

Through the Foresight Energy Infrastructure Partners II (FEIP II) fund, we are actively building a portfolio that aligns not only with decarbonisation goals, but with the operational realities of power system transformation. That means seeking out assets and platforms that can deliver energy, flexibility, and stability, often through hybrid or integrated structures.

4.1 Storage as Infrastructure

One of FEIP II's defining themes is grid-scale battery storage. In the UK, Foresight has acquired and scaled what is now the country's largest operating fleet of two-hour BESS assets. These batteries are strategically sited in constrained grid zones and are active across a stack of value streams, including:

- Dynamic containment and other frequency services
- Wholesale trading
- Capacity market participation
- Local balancing and congestion relief

Importantly, these assets have also been optimised for grid resilience value, providing firming, ramping, and (in future iterations) grid-forming capabilities. They are not just arbitrage tools; they are system assets.

4.2 Grid Infrastructure

FEIP II is also exploring projects and platforms in the grid domain, both regulated and merchant. This includes potential co-investments in:

- Regional interconnectors that support cross-zonal balancing and reduce congestion risk.
- Grid-adjacent development such as DC-AC converters and synchronous condensers, increasingly required in weak-grid zones as part of compliance packages.

In parallel, Foresight is engaging with regulators and TSOs to understand emerging system needs, positioning the FEIP II portfolio to anticipate future stability requirements, rather than merely respond to them.

5. Conclusion: From transition to transformation

The energy transition's early phase was defined by ambition, gigawatts of wind and solar, national targets, and landmark decarbonisation commitments. But ambition alone does not power economies. Systems do. And the systems that underpin the new energy economy are increasingly defined not by what they generate, but by how they withstand stress, manage volatility, and recover from shocks.

This is the resilience opportunity.

Investing in resilience is not merely about risk mitigation. It is about aligning capital with the direction of the system. Foresight is committed to identifying, enabling, and scaling those assets across an investable system we believe will keep the lights on quietly, reliably, profitably.

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