

CLOSING THE FLEXIBILITY GAP

Energy Flexibility White Paper

JUNIPERASSETS



Executive Summary

The next phase of the energy transition is about building energy flexibility, not simply adding more renewable generation capacity.

Across more developed economies, renewable energy has become a mainstream source of electricity, shifting the central challenge towards integrating increasingly variable generation while reliably meeting rising demand from electrification, digital infrastructure and artificial intelligence. The future power system will therefore depend not only on clean generation, but also on the infrastructure that enables it to operate efficiently, reliably and at scale.

Key Takeaways:

- Energy flexibility is essential infrastructure — the next major investment theme following renewable generation's rapid expansion.
- A widening flexibility gap: demand across Japan, Australia and Germany rises from ~105GW in 2026 to 269GW by 2050.
- Missing flexibility already cannibalises renewable value through rising curtailment, negative prices and depressed capture rates in mature markets.
- Four megatrends drive investment: AI and data-centre load, longer-duration storage, grid-forming stability, and flexible gas.
- Sector growth alone won't deliver returns — grid access, durable contracts and local execution separate the winners.

The global energy system is consequently becoming more complex. As renewable generation and distributed energy resources expand, and as transport, industry and buildings become increasingly electrified, electricity networks must connect millions of new assets, manage increasingly dynamic two-way power flows and balance greater variability in both supply and demand. At the same time, rapid growth in artificial intelligence and data centres is creating large, concentrated and increasingly time-sensitive electricity loads, placing further pressure on power systems. Together, these structural trends are reshaping how electricity networks are planned, operated and invested in.

Energy flexibility is central to meeting this challenge. Flexible assets can warehouse surplus electricity, shift energy to periods of higher demand, and provide bridging power to serve new loads where grid congestion or lengthy connection timelines constrain access to power. They can respond rapidly to changes in data-centre and system loads, provide critical services that stabilise the grid, and help defer or reduce the need for costly grid upgrades and new peak-generation capacity. Demand for these capabilities grows structurally as renewable penetration and electricity consumption increase, yet investment in flexibility is lagging renewable deployment in many markets. This is creating a significant and expanding “flexibility gap.”

Across major advanced markets such as Japan, Australia and Germany, required flexibility capacity is projected to increase from approximately 105 GW in 2026 to 145 GW by 2030 and 269 GW by 2050. The corresponding investment requirement is estimated to rise from approximately US\$117 billion in 2026 to US\$162 billion by 2030 and US\$247 billion by mid-century.¹

This paper examines **energy flexibility as the next major infrastructure investment theme** following the expansion of renewable generation. It outlines the structural drivers of demand — including renewable integration, electrification, and AI and data-centre growth — the scale of the investment opportunity, and the role that flexible infrastructure can play in enabling the next stage of the energy transition.

For investors seeking exposure to global electrification, decarbonization and digitalization, energy flexibility provides access to essential real assets positioned at the heart of the future power system. These assets can support continued renewable deployment, accommodate new sources of power demand and strengthen system resilience, while offering the potential for attractive infrastructure-style returns. For portfolios already materially exposed to renewable generation, flexibility assets, including storage and grid-supporting infrastructure, also provide an opportunity to diversify across technologies, revenue sources and market dynamics, potentially enhancing overall portfolio resilience.

¹ Juniper Assets analysis based on Aurora Energy Research (2026). Aurora data is provided on a no-further-disclosure basis. Aurora accepts no responsibility or liability for any use of, or reliance on, such data by other recipients.



What Is Energy Flexibility?

As renewable penetration and electricity demand rise, three distinct system needs grow simultaneously:

Stability (seconds to minutes)



With the retirement of conventional generators, the system needs fast-responding resources to hold frequency steady through demand fluctuations, forecast errors and sudden plant or transmission failures.

Energy Shifting (hours within the day)



Solar generation typically peaks at midday, while electricity demand and prices often peak in the evening. Flexibility assets capture low-cost or otherwise curtailed power during surplus periods and discharge it when the system needs it most.

Firm Capacity (days to seasons)



The system must still meet demand reliably through peak periods and extended stretches of low wind and sun, even as conventional generators retire.

Energy flexibility is a power system's ability to adjust electricity supply and demand across timescales ranging from fractions of a second to entire seasons, keeping the two continuously balanced. Because electricity cannot yet be stored at scale within the grid itself, generation must match consumption at every moment while system frequency remains within tight limits. Flexibility encompasses the resources that make this balance possible.

For most of the past century, flexibility was not a distinct product. Coal, gas and hydro supplied it as a by-product of generating energy – they ramped output up and down to follow demand, and their heavy rotating turbines stabilised frequency automatically. There was no need to price flexibility separately, because the generation fleet provided it inherently.

The energy transition changes this.

Renewable technologies such as solar and wind are now the greenest and lowest-cost sources of electricity in most markets, but they generate according to weather conditions rather than demand. They introduce forecast uncertainty and displace the dispatchable plants that historically balanced the system.

At the same time, AI and data centres are creating a new source of large,

concentrated and round-the-clock electricity demand. Their stringent uptime requirements mean that supply must remain reliable even during grid constraints, renewable shortfalls and system disturbances.

Flexibility assets can help data centres secure earlier grid connections, manage peak demand, firm intermittent renewable power and provide backup capacity. AI-driven demand therefore reinforces the need for flexibility on both sides of the system, supporting variable renewable generation while serving rapidly growing, reliability-sensitive loads.

A range of technologies provides energy flexibility, with each playing a complementary role across different timescales and system requirements. Pumped hydro is well suited to shifting large volumes of energy across hours or days. Flexible gas generation (commonly known as gas peakers) provides dependable capacity during periods of peak demand or low renewable output. Demand response adjusts consumption to prevailing system conditions, while interconnectors allow regions to share available generation and balancing resources. Grid-scale batteries are particularly well suited to flexibility requirements spanning seconds to hours, combining rapid response, modular deployment and increasingly competitive costs.



The Global Flexibility Gap

Flexibility demand rises with renewable penetration, but it is also being amplified by load growth, electrification, data-centre expansion, the retirement of dispatchable generation, grid congestion and increasingly volatile weather.

Climate cycles such as El Niño add a further layer of multi-month volatility, swinging hydro availability, cooling demand and wildfire risk across entire regions. Investment in the assets needed to balance the system and maintain reliability has yet to keep pace. The difference — the flexibility gap — can be estimated from power market fundamentals.

Analysis prepared for Juniper Assets, based on Aurora Energy Research data, projects flexibility capacity demand across five key markets as follows:

Flexibility Capacity Demand By Market and Country



Figure 1: Flexibility capacity demand by market, 2026–2050 (GW)

Source: Juniper Assets analysis based on Aurora Energy Research (2026). Aurora data is provided on a no-further-disclosure basis. Aurora accepts no responsibility or liability for any use of, or reliance on, such data by other recipients.

Across Japan, Australia and Germany alone, flexibility capacity demand grows from approximately 105 GW in 2026 to 145 GW by 2030 — 40 GW of additional demand in four years — and 269 GW by 2050. The corresponding investment demand rises from roughly US\$117 billion in 2026 to US\$162 billion by 2030 and US\$247 billion by 2050.²

Flexibility demand is met by a mix of technologies — batteries, pumped hydro, flexible gas, demand response — but grid-scale batteries are the most scalable and fastest to deploy, with construction timelines of 12–24 months and few siting constraints. They are accordingly capturing the majority of new flexibility investment in most major markets.

² Juniper Assets analysis based on Aurora Energy Research (2026): flexibility capacity and investment demand projections for Japan, Australia (NEM), Germany, Spain and the United Kingdom.

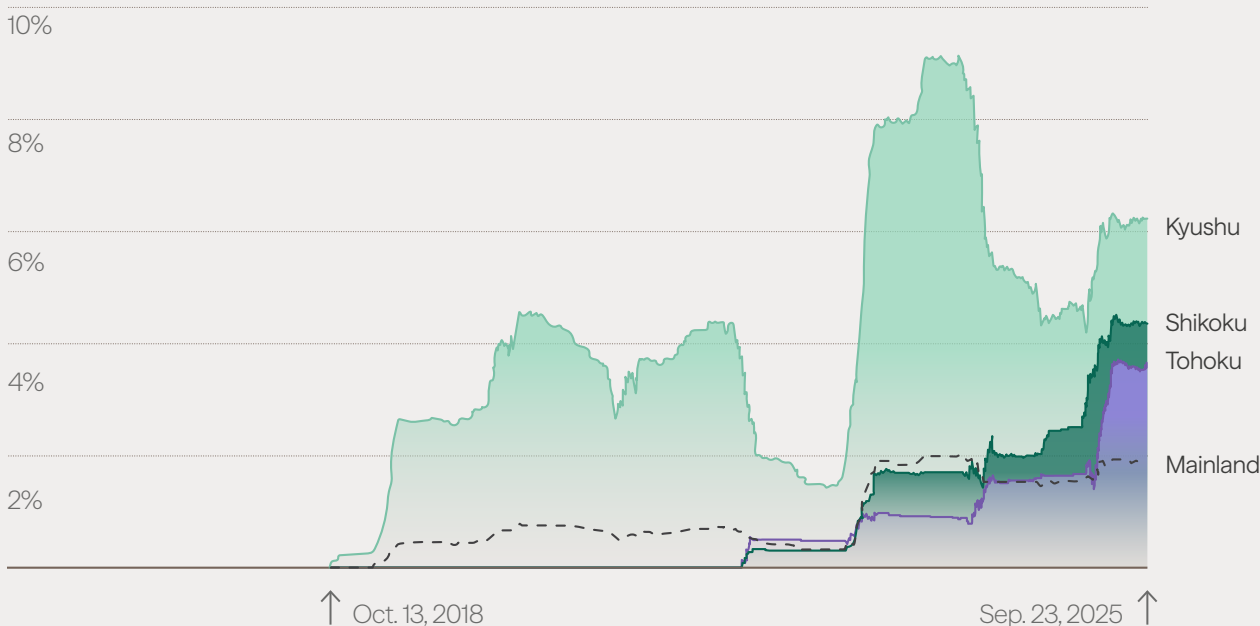


The Cost of Missing Flexibility: Renewable Value Cannibalisation

The shortage of flexibility is already affecting the economics of renewable generation. Wind and solar assets within the same market tend to generate at similar times. When output is abundant, wholesale prices fall—sometimes below zero—reducing the price earned by renewable generators.³ In the most affected European markets, wind projects capture only 55–65% of the average annual electricity price, while solar projects capture 45–65%. Negative-price hours increased from approximately 200 in 2020 to more than 500 in 2025.⁴

Japan illustrates how rapidly renewable curtailment can escalate when flexibility infrastructure fails to keep pace. In Kyushu, the country's most solar-intensive region, the 365-day rolling solar curtailment rate approached 10% in 2024 and has remained above 6% through 2026.

365-Day Rolling Solar Curtailment Rate by TSO Area
October 13, 2018 - September 23, 2025



Note: Solid lines represent the 365-day rolling solar curtailment rates (curtailed output as share of the sum of generated and curtailed output) for Japan's nine mainland TSO areas; dashed line represents combined figure. Calculated based on each TSO's 30-minute supply and demand data (as of Sep. 23, 2025).

Source: Japan Energy Hub 2025

This creates a **growing need for assets that can store, shift or redirect electricity** from periods of surplus to periods of higher demand. Additional renewable capacity alone does not resolve the mismatch between when power is generated and when it is needed. While subsidies and price guarantees can protect individual projects, flexibility addresses the underlying system imbalance.

³ Boston Consulting Group, "Flexibility, Not Capacity, Will Decide Renewable Energy's Future," February 2026.

⁴ Boston Consulting Group, "Flexibility, Not Capacity, Will Decide Renewable Energy's Future," February 2026.



Four Megatrends Driving Flexibility Investment



The widening flexibility gap reflects a growing shortage of critical infrastructure required to integrate renewable generation while maintaining system reliability. We have identified four structural megatrends that we believe will shape the next phase of investment in energy flexibility and create compelling opportunities for long-term infrastructure capital.

Flexible Assets Unlock Constrained Grids

Flexible infrastructure is becoming critical to connect new power demand, accelerate grid access and support the growth of the AI and digital economy.

1. Flexible Assets to Unlock Grid Constraints and Power the AI Economy

For the first time in a generation, many developed power systems are experiencing material demand growth, driven by data centres, AI infrastructure, advanced manufacturing and broader electrification. In many markets, the principal constraint is not simply the availability of new generation, but the ability of the grid to connect and deliver power where it is required. Connection queues can extend for years, while shortages of transformers, substations, transmission capacity and skilled construction resources limit the pace of conventional network expansion.

Flexible assets provide a faster and more targeted response to these constraints. When located at a constrained grid node, a battery can charge when local generation exceeds available network capacity and discharge during periods of peak demand. This can reduce renewable curtailment, relieve congestion and defer selected network reinforcements.

Bridging power provides a complementary solution where the constraint is the timing or availability of the grid connection itself. Dispatchable generation can provide reliable on-site or near-site power to enable data centres and other large loads to energise or expand before permanent grid capacity becomes available. As grid infrastructure is delivered, bridging generation can transition from primary supply towards backup, peaking or other flexible capacity, allowing infrastructure to be deployed ahead of conventional grid timelines.

For data centres and other large power users, these solutions can be combined to create a more flexible power-supply proposition. Batteries can limit peak grid demand, manage rapid changes in consumption and support staged or flexible grid connections, while bridging power can provide firm capacity during periods when grid supply is unavailable or insufficient. Together with renewable generation, these assets can support earlier energisation and phased expansion while providing the high levels of reliability required by digital infrastructure.

Recent transactions in markets such as Australia indicate that this is developing into a broader commercial model. Long-term electricity supply arrangements for AI and digital infrastructure are increasingly being coordinated with renewable procurement, storage, flexible demand and dispatchable capacity. These structures can provide customers with greater certainty over time-to-power and reliability, while long-term contractual revenues support the financing of the underlying flexible assets.

For investors, this creates two related sources of value. First, grid constraints can be monetised through locational price spreads, reduced curtailment, network services and long-term power arrangements with large energy users, while bridging solutions can capture the value associated with accelerating access to power. Second, credible grid positions and sites capable of supporting flexible power infrastructure in constrained locations are scarce and difficult to replicate. Flexible assets are therefore emerging not only as enabling infrastructure for renewable integration, but as critical infrastructure for overcoming grid constraints and supporting the growth of the AI and digital economy.



Longer-duration Storage Expands the Opportunity

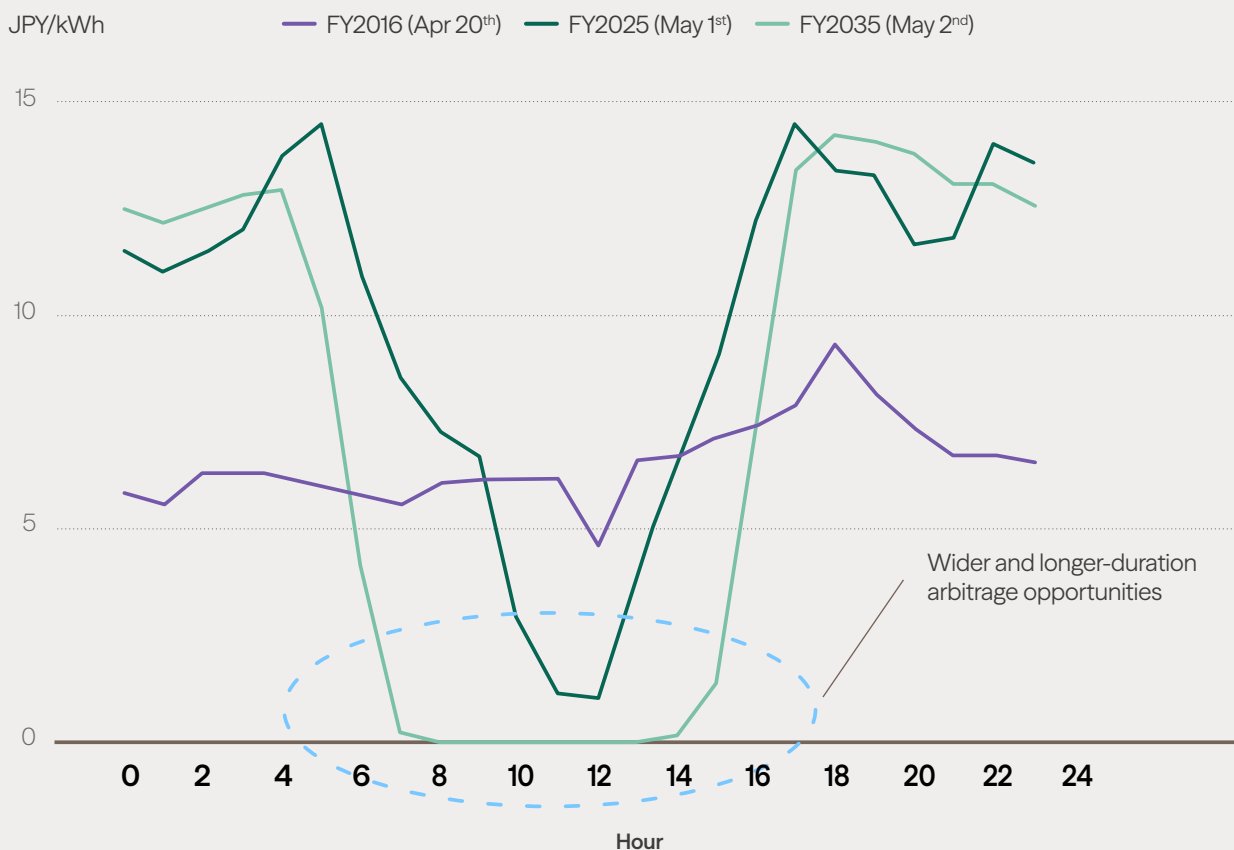
Longer-duration storage can capture a broader revenue pool as renewable surpluses extend beyond conventional battery discharge periods.

2. Longer-duration Energy Storage

Most grid-scale batteries deployed today are designed for short-duration applications, including frequency response and intraday energy shifting in the range of 3–4 hours. **The market for energy storage is expanding beyond short-duration batteries.**

Japan's projected wholesale price curves demonstrate why longer-duration storage is the next evolution of the market. By FY2035, Aurora Energy Research forecasts prices at or near zero for up to eight consecutive daytime hours—well beyond the discharge duration of conventional 3–4 hour batteries. As renewable surpluses extend, the ability to capture and shift this additional low-cost energy increasingly becomes the key source of value, favouring longer-duration storage over conventional lithium-ion systems.

Wholesale Power Price (Japan Nationwide, Clear Sky Weekday in Spring)



Source: Aurora Energy Research 2026



Three structural trends are increasing the importance of longer-duration assets and broadening the range of investable technologies.

2.1 Government tenders are increasingly prioritising duration

Public procurement programmes are moving from supporting battery capacity in general to procuring longer-duration capability. In New South Wales, Long-Term Energy Service Agreement tenders require storage projects to discharge continuously for at least eight hours and provide access to competitively determined minimum revenue support. In Japan, the Long-Term Decarbonisation Power Source Auction excluded batteries with less than six hours of duration. Half of the combined procurement ceiling for batteries and pumped storage was allocated to a category covering non-lithium batteries, new pumped storage and other long-duration storage technologies. These programmes indicate that governments increasingly value the duration, availability and reliability that storage provides—not simply its power capacity.

2.2 Longer duration can capture a broader revenue pool

As renewable penetration increases, periods of surplus generation and power scarcity will become longer. Storage will increasingly need to shift electricity from daytime into the evening and overnight, and eventually across multi-day periods of low renewable output. Longer-duration assets can participate across energy arbitrage, capacity, firming and reliability markets, reducing their dependence on increasingly competitive short-duration ancillary services.

Duration is therefore becoming a commercial design decision: the optimal configuration should reflect the shape of local price volatility and the services being procured.

2.3 Longer-duration requirements will support technology diversification

Lithium-ion batteries will remain important, particularly for four- to eight-hour applications, but may not be the most economic solution for every duration or operating profile. Longer-duration requirements are expanding the addressable market for alternative technologies—including sodium-ion, flow batteries, pumped hydro and thermal storage—which may offer lower incremental energy costs, longer operating lives, improved safety or greater supply-chain diversification.

This transition is already moving beyond demonstration projects. Japan's latest LTDA awarded approximately 0.7 GW of non-lithium battery capacity, demonstrating that alternative storage technologies can compete at commercial scale when supported by an appropriate long-term procurement framework. This creates an important pathway for proven technologies to establish operating records, expand manufacturing capacity and attract institutional capital.

For investors, longer-duration and emerging technologies can provide access to long-term, policy-supported revenues. Capturing this opportunity requires disciplined structuring that aligns contract tenor with asset performance and allocates construction, availability, degradation and replacement risks to capable counterparties. Strong warranties, performance guarantees and credible suppliers are essential to converting government support into bankable infrastructure returns.



Grid Stability Becomes a Contracted Service

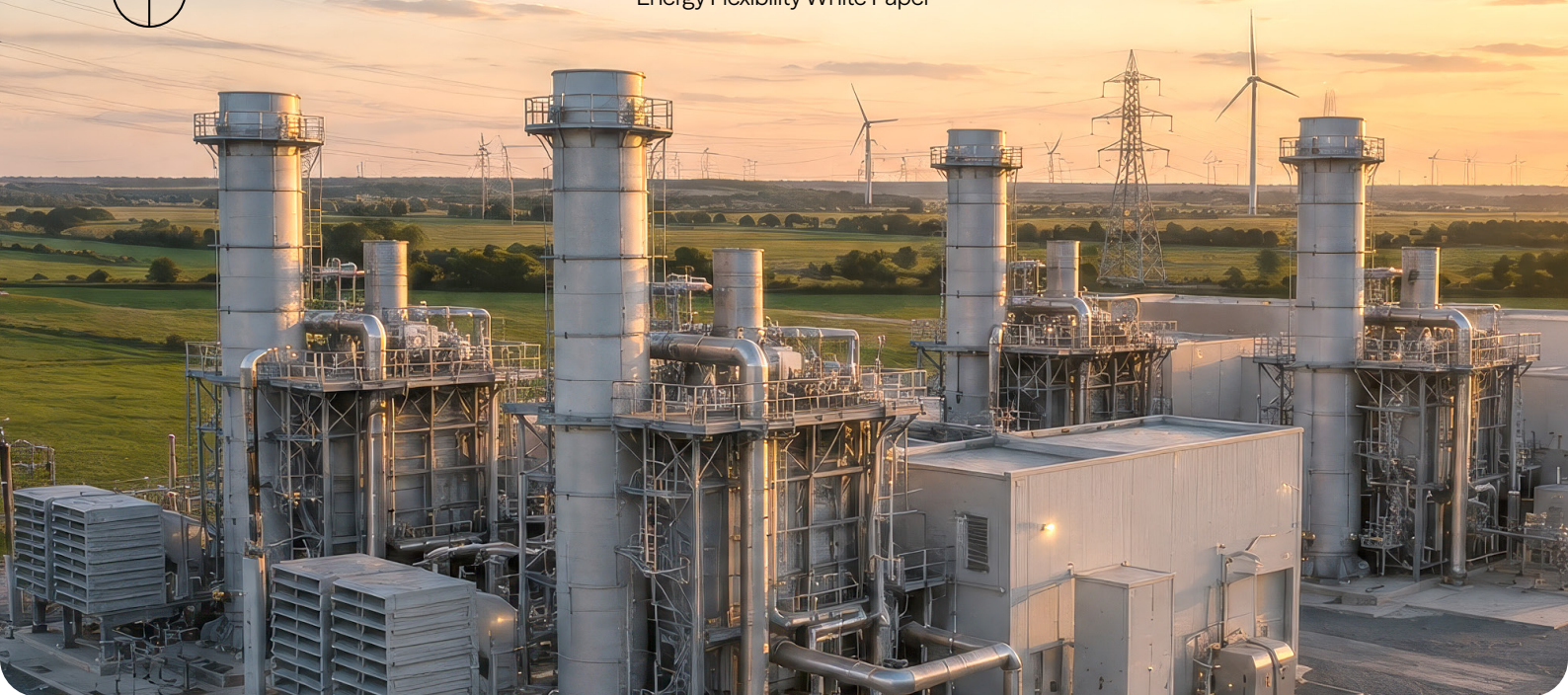
As conventional generators retire, grid stability is becoming a separately procured service, creating new contracted revenues for advanced flexibility assets.

3. Grid-Forming: Stability Becomes a Contracted Revenue Stream

Conventional coal, gas and nuclear generators have historically supported grid stability through the natural inertia of their rotating turbines. This inertia slows sudden changes in system frequency and gives network operators time to respond to disturbances. As conventional generators retire and are replaced by inverter-based wind, solar and battery assets, this stabilising capability also disappears. While decarbonisation changes how electricity is generated, it does not eliminate the need for inertia and system strength. These services must instead be provided through new technologies, creating an emerging investment opportunity in grid-forming batteries and other advanced flexibility assets. Batteries equipped with grid-forming inverters can provide this replacement service. Unlike conventional grid-following systems, which depend on an existing stable grid signal, grid-forming batteries can help establish and maintain voltage and frequency. They respond almost instantaneously to disturbances and can provide stability without requiring significant energy discharge. This capability must, however, be incorporated into the power-conversion system, controls and certification process from the outset.

Germany provides a clear example of this technical requirement becoming a contracted revenue stream. In January 2026, Germany's four transmission system operators began procuring instantaneous reserve, or grid inertia, from qualifying assets, including batteries with grid-forming capability. The framework provides fixed, availability-based payments under multi-year commitments. This creates an additional contracted revenue stream that can be combined with energy trading and balancing income.

For investors, the opportunity arises as stability services historically provided implicitly by conventional generators are separated, procured and priced by the private sector. Specifying grid-forming capability can provide access to additional contracted revenues and preserve optionality as similar markets develop.



Flexible Gas Provides Firm Capacity

Batteries and flexible gas are complementary, combining rapid-response flexibility with firm capacity during prolonged periods of low renewable output.

4. Flexible Gas to Bridge the Coal Phase-out

Flexibility is a system requirement, not a single technology. Batteries are highly effective at managing intraday volatility, shifting electricity into peak periods and providing rapid-response services. However, power systems must also manage extended periods of low wind and solar output. As coal-fired generation retires, the multi-day and seasonal reliability it historically provided must be replaced through a combination of longer-duration storage, interconnection, demand response and dispatchable generation.

Flexible gas generation is expected to remain an important source of firm capacity where other technologies cannot yet address prolonged supply shortfalls economically or at sufficient scale. Australia illustrates this requirement. AEMO's 2026 Integrated System Plan projects that most of the National Electricity Market's remaining coal capacity will retire by 2035. Its optimal development pathway includes substantial investment in storage alongside a flexible gas fleet capable of maintaining reliability during extended periods of low renewable output.⁵

The same combination is emerging as a solution for data centres facing long grid-connection delays and highly demanding load profiles. BloombergNEF has tracked 4.9 GW of announced battery capacity co-located with on-site conventional generation at data centres—approximately one-third of announced global on-site data-centre battery capacity⁶. In these configurations, gas provides sustained power while batteries respond immediately to computing-driven demand spikes, bridge generator ramping periods and reduce frequent cycling of generation equipment. Hybrid systems can also enable data centres to begin operations before permanent grid capacity becomes available.

For investors, batteries and flexible gas should therefore be viewed as complementary rather than competing technologies. Batteries address rapid-response and daily balancing requirements, while gas provides sustained capacity during longer and less predictable shortfalls. Platforms capable of combining both technologies—and structuring solutions for grids, utilities and large power users—will be better positioned to serve the full duration curve of flexibility demand.

⁵ AEMO 2026 Integrated System Plan

⁶ BloombergNEF 2026



Conclusion and Key Considerations

Energy flexibility is not simply a sub-theme of the energy transition – it is essential infrastructure upon which the transition increasingly depends. Renewable generation is scaling rapidly, but power networks were not designed to manage electricity that is intermittent, decentralised and increasingly difficult to transport. Across Japan, Australia and Germany, flexibility demand is projected to increase by approximately 40 GW between 2026 and 2030, requiring an estimated US\$45 billion of investment.

Grid-scale batteries are the leading near-term solution, supported by more than 100 GW of global deployment, an active transaction market and financing structures tested across multiple jurisdictions. The opportunity is also broadening into longer-duration storage, grid-forming services and flexible generation as power systems seek solutions across the full duration curve.

The investment case is not tied to a single market or revenue model. Exposure across markets with distinct regulatory frameworks, weather patterns, commodity dynamics and revenue structures can provide meaningful portfolio diversification. However, experience in more mature markets shows that sector growth does not automatically translate into attractive returns. Scarce grid access, durable contracts and proven operating capabilities become more valuable. Investment outcomes will therefore depend on disciplined market entry, asset location, contract quality and operational execution.

Investors should focus on four factors when evaluating the opportunity:

1. Asset and Market Fundamentals

Projects should be underwritten against clearly identified system needs, credible grid access, strong site selection and durable demand. Market growth alone cannot compensate for a weak connection position, a poorly located site, an asset mismatched with local requirements or material ramp-rate restrictions that constrain its operational flexibility.

2. Contract and Revenue Resilience

Revenue structures should provide sufficient downside protection while preserving selective exposure to long-term market upside. Investors should assess the quality of the contractual framework—including tenor, indexation, availability obligations, revenue sharing and termination provisions—rather than relying only on the headline contracted percentage.

3. Operating and Execution Capability

Flexibility assets require active management throughout development, construction and operations. Technology selection, procurement, contracting, financing, dispatch optimisation and lifecycle management can materially affect realised returns.

4. Local Market Expertise and Partnerships

Power markets remain highly jurisdiction-specific. Grid rules, permitting, contracting practices and regulatory frameworks differ significantly between markets. Local relationships and execution capabilities are therefore critical to sourcing opportunities, navigating approvals and responding to regulatory change.

Investors evaluating energy-transition opportunities should focus on scalable projects underpinned by strong demand fundamentals, contracted revenue streams designed to withstand market cycles, demonstrated track records and deep local-market expertise. Those able to leverage local partnerships, navigate regulatory complexity and execute efficiently will be best placed to deliver sustained value as the transition thematic advances.



Sources and Notes

This paper draws principally on the following market research, used under license, together with public policy documents and transaction announcements:

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- Japan Energy Hub, 2025
- Ministry of Economy, Trade and Industry (METI), Japan, 2026
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- Boston Consulting Group, “Flexibility, Not Capacity, Will Decide Renewable Energy’s Future,” 2026

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we aim to deliver long-term value while contributing to a more sustainable and secure future.

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