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The Synergies of Flow Battery–Gas Plant Hybrids for Increased 2-Way Flexibility

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As Europe moves closer to achieving its decarbonisation goals, the spotlight is shifting towards a less noticeable yet increasingly vital component of the clean energy landscape: grid flexibility. Besides peaker plants for peak power on demand, energy storage allows for additional flexibility to store excess energy, and then discharge this stored energy when it is needed.

To address longer durations of excess energy, flow batteries provide an economical solution. Flow batteries, long considered a niche part of the energy storage market, are now showing significant potential to provide the quick, dependable, and scalable backup power needed by a grid with a high proportion of renewable energy sources. Their ability to store surplus electricity for several hours, or even days, and dispatch it during periods of peak demand makes them particularly well suited to the modern grid, which is shaped by the variability of wind and solar power. As the amount of excess power from renewables grows, the longer storage duration of flow batteries makes them an increasingly attractive option to add flexibility to the grid.

Integrating the flow batteries into existing, or new gas peaking plants creates a hybrid system that can leverage the strengths of both technologies, combining the fast, long-duration storage capabilities of flow batteries with the dispatchable reliability of gas turbines, inertia and supply in times of lagging renewable energy availability. This pairing improves efficiency, reduces operating costs, and unlocks multiple revenue streams while supporting the transition to a cleaner and more flexible grid.

Why grid flexibility is needed and how flow batteries can be part of the solution

Without flexibility, the electricity grid cannot keep supply and demand in real-time balance, putting both reliability and stability at risk. As the share of variable renewable energy sources like wind and solar increases, so does the unpredictability and variability of generation. This creates challenges in matching supply to fluctuating demand and in managing sudden changes in weather or generation patterns. Flexibility allows the grid to respond quickly to these changes by adjusting generation, consumption, or storage, helping to prevent blackouts, reduce curtailment of renewable energy, and optimise the use of transmission infrastructure. Increasing curtailment capacity is also useful for enhancing grid security and resilience, so it is better able to handle unexpected voltage surges, such as the recent blackout on the Iberian grid.

Reducing costly curtailment is a key motivation for enhancing grid flexibility, through technologies like energy storage and demand response, to reduce the financial costs of curtailing energy, and enabling the use of renewable energy rather than wasting it. Curtailment occurs when available electricity, often from renewable sources like wind or solar, must be reduced or turned off because the grid cannot absorb or transmit the excess energy. This typically happens during periods of low demand, limited transmission capacity, or grid congestion, especially in areas with high renewable penetration.

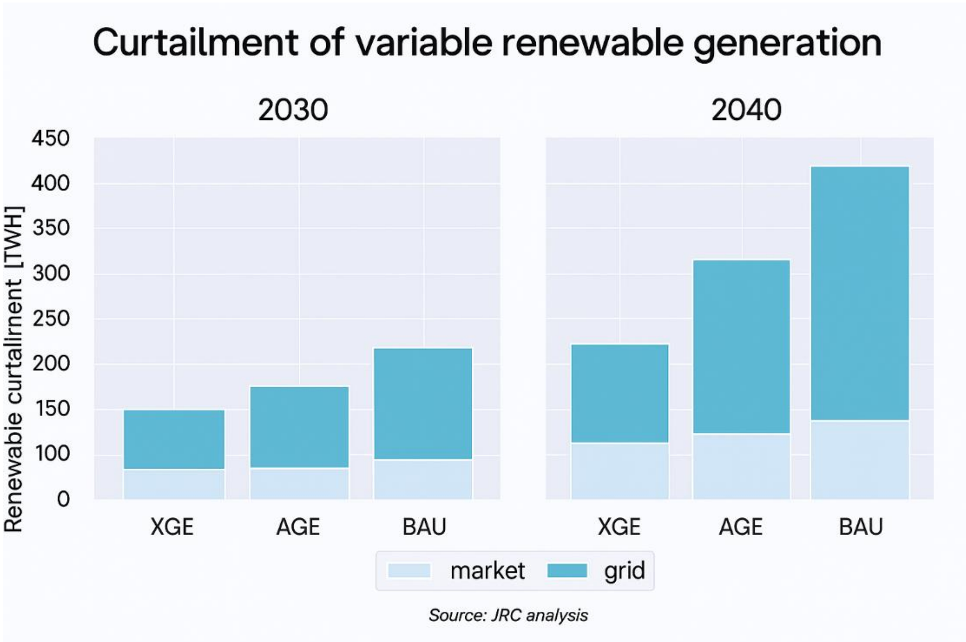

Figure 1.

While curtailment can help maintain grid stability, it also represents a lost opportunity to use clean, low-cost energy and can undermine the economic viability of renewable projects. Today's coverage of renewable energy exceeds 50%, and many countries already have a regular surplus. Further expansion of renewable energy sources leads to even more surplus, in an already congested grid. In 2024, 3.5% of renewable energy generation in Germany was curtailed, costing grid operators €554 million in compensation (PV Magazine, 2025). In July 2025, renewable energy curtailment in Spain reached a record high of 11%, highlighting the need for storage in its grid (strategic energy, 2025). On the EU level, a recent report by the European Commission's Joint Research Centre (JRC) on grid congestion redispatching volumes shows that renewable electricity curtailment could reach 310TWh by 2040 in a business-as-usual scenario (figure 1 - JRC, 2025). At current average EU wholesale market prices, this would cost EU grid operators around

€26 billion.[1] This shows that other solutions are necessary to avoid the unnecessary waste of surplus energy.

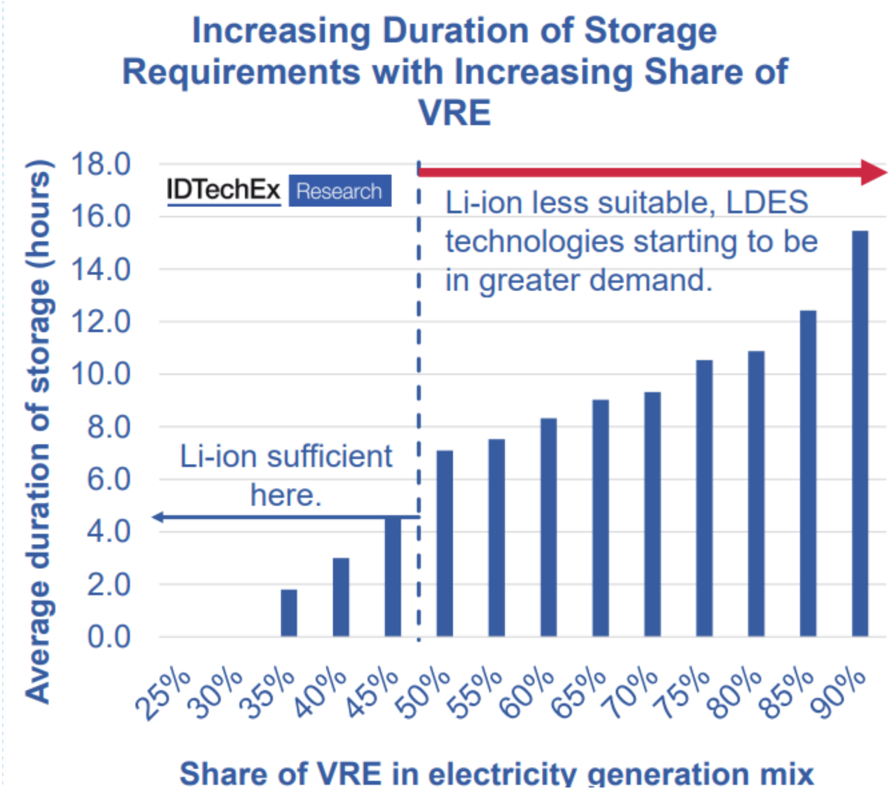

Figure 2

The energy storage market currently requires around 4-6 hours of discharge duration to efficiently use the electricity generated from renewables, and soon overnight storage of up to 14 hours will be needed to achieve higher renewable coverage in the grid, as seen in figure 1 (IDTechEx). Long Duration Energy Storage (LDES) technologies are starting to be in greater demand as the share of variable renewable energy (VRE) increases in the electricity generation mix, with short duration lithium ion insufficient after 50% share of VRE (IDTechEx, 2024). Flow batteries can provide short term ancillary services and short duration, and can also go as far as seasonal energy storage when combined with

[1] FBE own calculation using EU member state wholesale electricity prices from September 2025, with €0.084 /kWh as EU average. Data from Ember-energy.org. https://ember-energy.org/data/european-electricity-prices-and-costs/

gas peakers, and avoid the high costs of grid extension. Therefore, a flow battery with gas peaker hybrid system is the most resilient, as well as the most cost-effective solution.

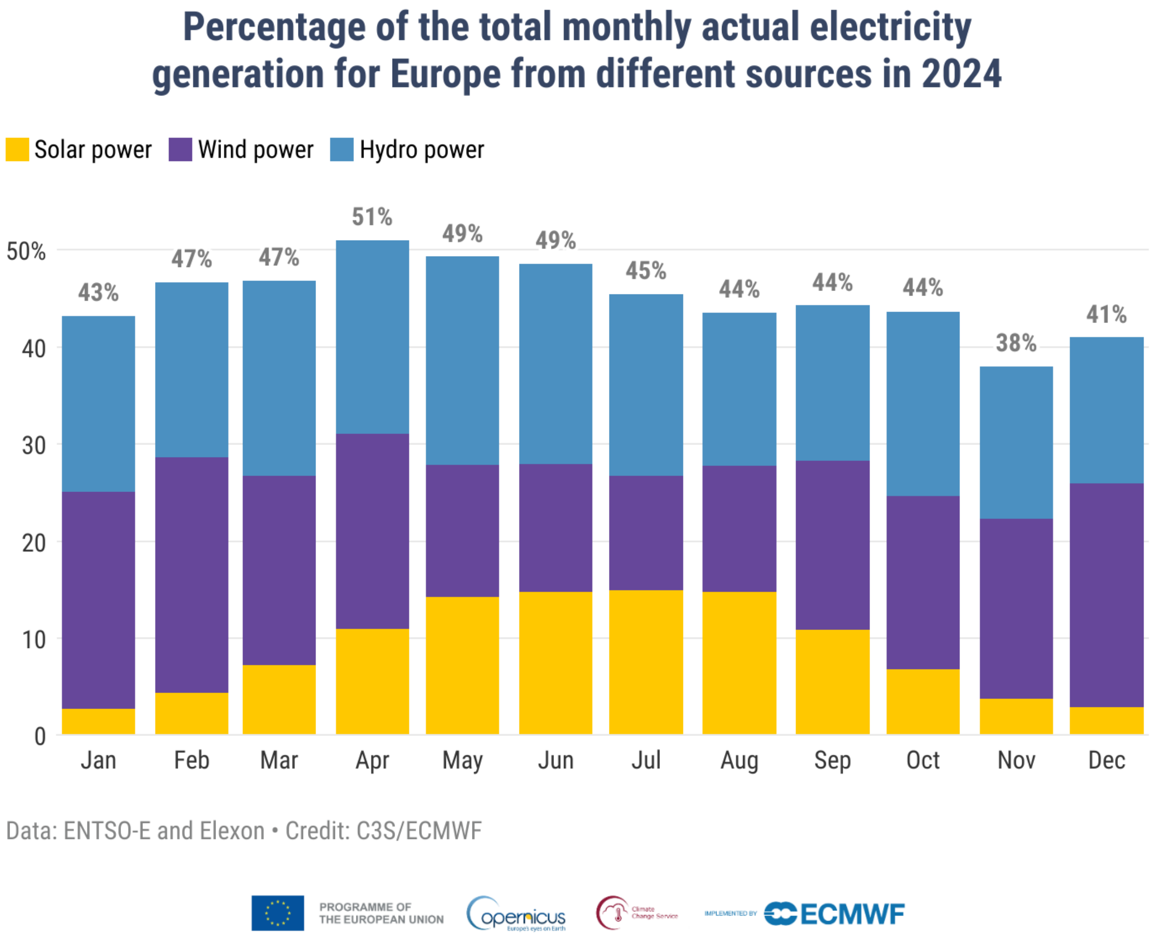

Figure 3.

Increasing storage capacity particularly through long-duration systems such as flow batteries can help reduce renewable energy waste and lower the costs associated with curtailment. Figure 3 shows the variability of renewables generation throughout the year with a 13% variation between the highest and lowest point, and intraday variability can be up to 100%. This variation exemplifies the necessity for long duration storage, to compensate for the variability, to smooth our cloudy windless days, multi-week renewable lulls, and to capture the months of excess generation to save for months with low generation. Flow batteries differ from conventional lithium-ion technologies in terms of both their chemistry and how they function. Rather than storing energy in solids, the energy is stored as non-flammable liquid electrolytes in external tanks. This architecture enables cost competitive longer storage durations especially due to independent scaling of power and capacity. In addition, a longer cycle life, non-flammability, reduced degradation over time, and scalability making them particularly suitable for stationary grid applications. While costs depend significantly on the application, the longer lifetime, lack of degradation, and lower maintenance cost often make them the cheaper option over time compared to conventional lithium ion, particularly for longer duration storage, see figure 4.

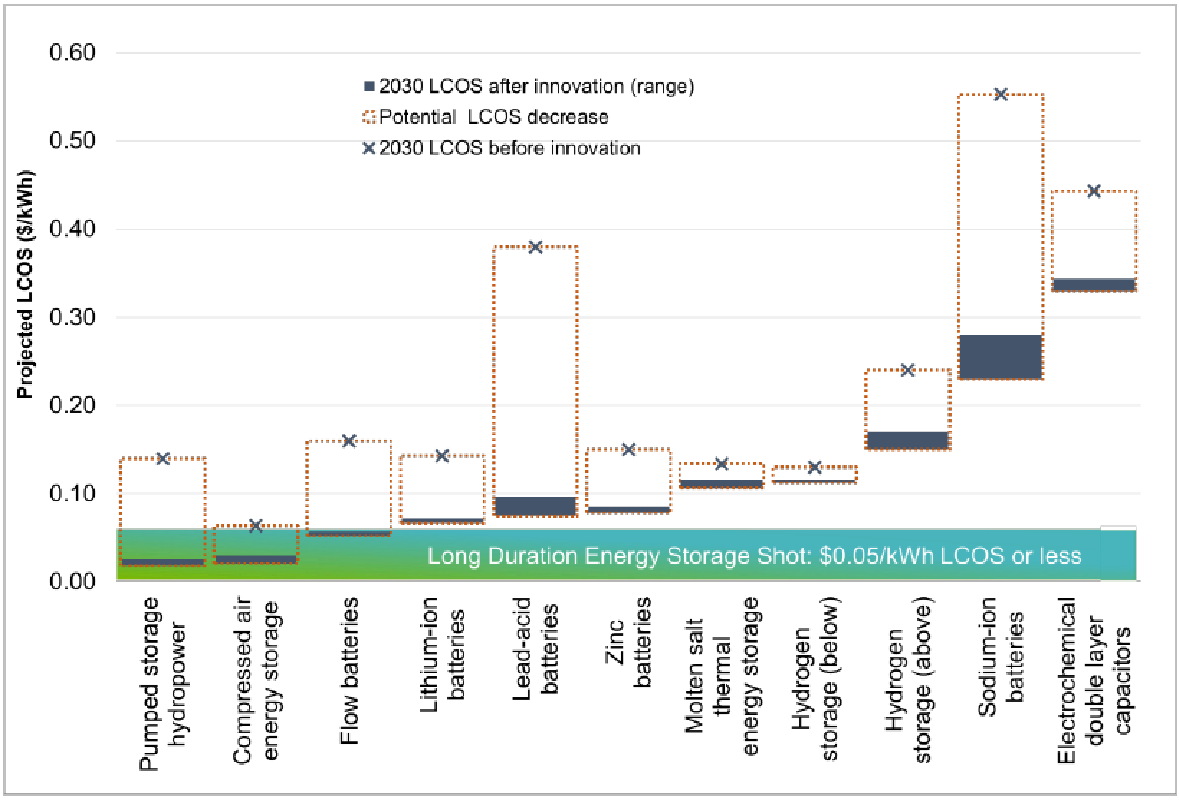

Figure ES1. For long duration energy storage, the range of impact on the 2030 LCOS after mplementing the top 10% of LCOS-reducing innovations. Above and below ground hydrogen storage are shown separately. LCOS: levelized cost of storage

Figure 4.

Costs for flow batteries are expected to come down significantly as the industry scales, benefiting from the same scaling factor dynamics that drove down prices in wind and solar. Improved design innovations, such as more compact stacks, better membranes, and simplified, scaled production will lower capital costs and boost efficiency. Electrolyte costs are also projected to decrease as vanadium recovery from byproducts expands and alternative chemistries like iron and organic gain traction. A Made in EU supply chain will reduce transportation costs and mitigate exposure to global market volatility. Finally, because the technology is still relatively early in its commercialisation compared to lithium-ion, there is substantial room for cost reductions as production processes mature, supply chains localise, and deployment scales across Europe. Costs of alternatives to new gas peaking plants are coming down, bringing the LCOE to comparable or even lower prices than gas generation (Lazard, 2025).

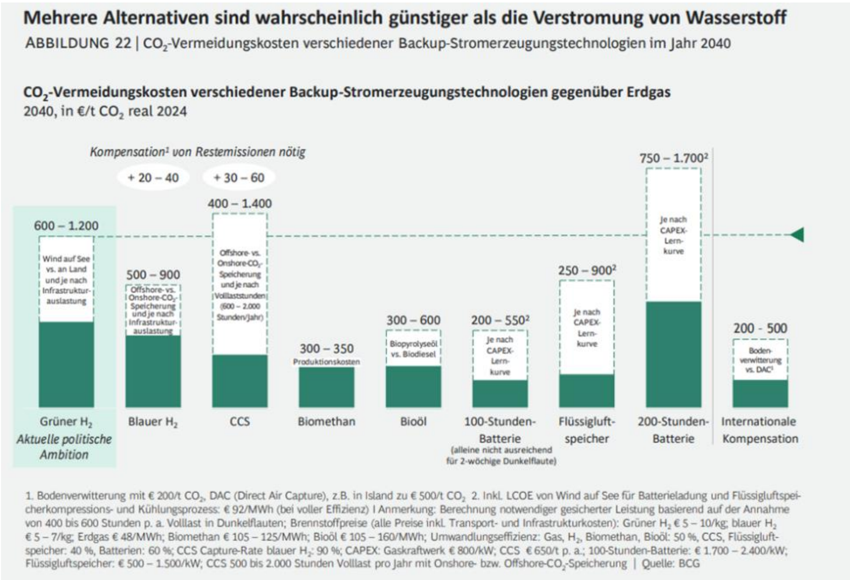

Figure 5

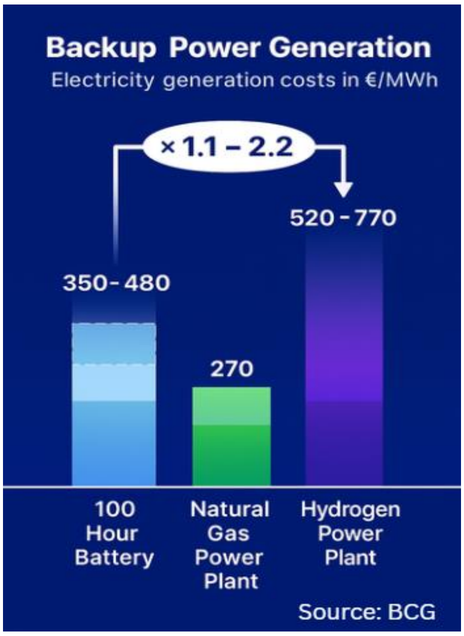

Figure 6. (Source: Boston Consulting Group)

Flow batteries are also increasingly cost competitive with hydrogen for long duration storage. As indicated in figure 5, 100-hour batteries which can be achieved by flow batteries – is a more cost-effective solution compared to hydrogen and CCS. 200-hour storage, which could also be achieved by flow batteries and be enough to last through a 2-week dunkelflaute (extended periods of low wind and low solar output), could become cost effective with a favourable CAPEX learning curve. Furthermore, a 100-hour battery is much more cost effective for backup power generation (figure 6).

Rather than relying on a single "silver bullet" to replace peaking plants, a hybrid approach offers the most realistic and effective way to capture the strengths of different technologies. Unlike lithium-ion systems, which depend on scarce and geopolitically sensitive raw materials, flow batteries can be built using abundant, non-toxic inputs, many of which are sourced within Europe. This opens the door to developing a domestic supply chain for clean energy storage, aligning directly with the goals of the EU's Clean Industrial Act, which requires at least 40% of key clean technology components to be manufactured within the EU. The case for flow batteries is further reinforced by the EU's Electricity Market Design reform, which seeks to modernise capacity mechanisms and promote low-carbon flexibility resources. By explicitly valuing fast-response, emissions-free storage technologies, the framework sends a clear regulatory signal: the future requires cleaner flexibility and cleaner peaking solutions.

Gas peaking plants continue to play a crucial role in the electricity grid because of their ability to provide fast, on-demand power during periods of peak electricity demand or when renewable generation falls short. Unlike wind or solar, which are weather-dependent, gas peakers can ramp up quickly and operate reliably at any time and duration, making them an important tool for maintaining grid stability and avoiding blackouts. They are particularly valuable during extreme, longer-lasting weather events (e.g. so-called Dunkelflaute), seasonal demand spikes, or sudden drops in renewable output. While not ideal from an emissions standpoint, gas peaking plants offer the flexibility and responsiveness that current storage and demand-side resources may not yet be able to provide at scale. As the grid evolves, their role is evolving as well.

The business case for combination of flow batteries with gas peaking plants

Experts are increasingly advocating a hybrid model, in which flow batteries are located alongside gas plants to mitigate their environmental impact and cut runtime. Each technology performs best over different timeframes: flow batteries are suited for short- to medium-duration storage (from minutes up to 200 hours), while gas turbines remain more economical for sustained operation lasting multiple days or weeks. On their own, each faces limitations, but in combination, they complement one another—bolstering flexibility while reducing costs and emissions. A hybrid approach has multiple advantages:

1. Faster response: Flow batteries respond instantaneously to frequency events, whereas gas turbines require minutes to ramp up.

2. Cleaner peaking: Batteries can handle short-duration peaks, meaning gas units can be reserved for periods of extended scarcity.
3. Improved economics: Reduced fuel use leads to lower operating costs and emissions fees.
4. Lower wear and tear of the gas turbines, saves maintenance costs.
5. Batteries add to grid flexibility as they can supply and store energy hence solving curtailment issues.

During periods of prolonged low renewable generation when there is no surplus to charge the battery with, it is especially useful to co-locate the battery with the gas peaker plant. With this configuration, the gas peaker plant may also recharge the battery, ensuring there is stored capacity and flexibility when needed, to provide fast ramp up and frequency response, allowing smooth output.

Integrating a battery system with a gas plant can also significantly reduce the investment costs of storage, since the two facilities share both grid connection, transformer, and permitting—major components of total capital expenditures (CAPEX). Operational expenses are also lowered in a hybrid setup, as the battery can be charged during periods of low demand, ensuring that the gas plant operates only when it can run at maximum efficiency. In addition, the battery system can deliver valuable ancillary services, such as primary frequency response, during times when the gas plant is offline.

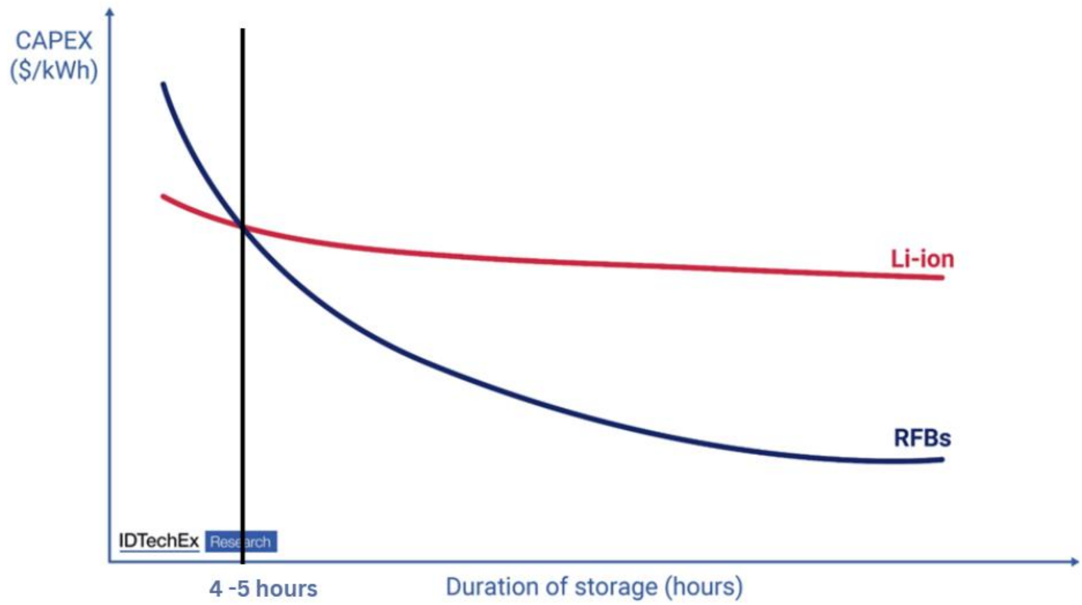

Figure 7.

As shown in figure 7, the longer energy is stored, the more cost-competitive flow batteries become compared to lithium-ion. This capability is critical for managing excess renewable generation, helping to prevent curtailment, reduce price volatility, and minimise the need for costly grid expansions. In periods of prolonged low renewable output, however, gas peaker plants remain necessary to safeguard system stability. In a hybrid configuration, flow batteries can provide ancillary services and short- to medium-duration storage, while gas peakers ensure backup during extended shortages. Together, they deliver both cost efficiency and resilience, addressing renewable oversupply as well as prolonged undersupply.

A hybrid system unlocks several revenue streams, many of which are stackable. As the battery charges during periods of overproduction, the stored energy can then be used for a multitude of services. Daily cycling of the flow battery allows it to participate in energy arbitrage when otherwise inactive, and can handle peak shaving by discharging during short term peak periods. Using the battery for these shorter periods also avoids inefficient cycling and wear on the gas turbine, saving fuel use and reducing operation and maintenance costs as the turbine is only needed for longer term operations where it is more efficient. On the regulatory side, both the battery and gas plant qualify as firm capacity in EU capacity market payments, allowing them to earn revenue just for having capacity available to supply power during peak demand. The hybrid plant can also bid into redispatch markets, helping to relieve grid congestion.

In summary, co-locating a flow battery with a gas peaking plant delivers substantial benefits across both revenue generation and strategic value. Combining a flow battery with a gas peaking plant creates an efficient hybrid system that enhances operational flexibility, reduces emissions, and opens new revenue opportunities. Flow batteries can handle frequent and extended cycling without degradation, making them ideal for daily energy arbitrage, frequency regulation, and peak shaving. By shifting short-duration (4 to 100 hours) and frequent-response duties to the battery, the gas plant avoids costly start-stop cycles, reduces fuel consumption, and lowers maintenance costs. At the same time, the combined system can still deliver firm capacity during peaks or emergencies, maintaining reliability during the days, weeks and months. This hybrid setup enables participation in a wide range of energy and ancillary service markets, creating a stacked revenue model that improves the economic viability of the asset. It also positions the plant for long-term value in a decarbonizing grid, aligning with emissions targets and regulatory pressures. In short, co-locating a flow battery with a gas peaker can thrive in a cleaner, more dynamic electricity market.

FOR FURTHER INFORMATION

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ABOUT FLOW BATTERIES EUROPE

Flow Batteries Europe (FBE) represents flow battery stakeholders with a united voice to shape a long-term strategy for the flow battery sector. We aim to provide help to shape the legal framework for flow batteries at the EU level, contribute to the EU decision-making process as well as help to define R&D priorities. Flow Batteries Europe is working to create and reinforce networks between key stakeholders in the flow battery industry. www.flowbatterieseurope.eu

For more information about the topic, you can see the White Paper: Battery Energy Storage Systems in Power Plants from Siemens Energy.

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