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Perspectives

Battery storage: Strategies for revenue stacking and investment success

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Audrey Lee | Research Analyst

Daniel McCormack | Head of Research

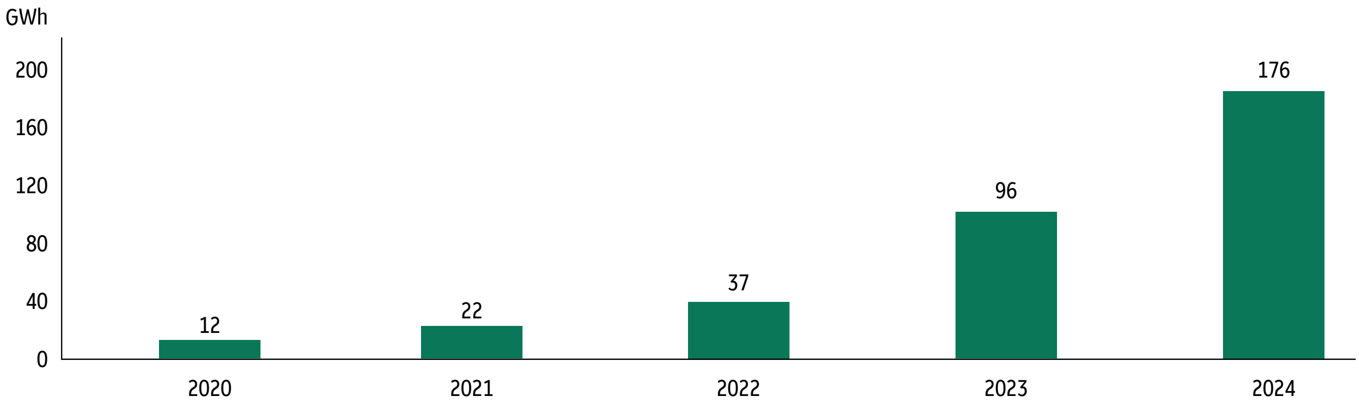
Executive summary

- **Investment opportunity:** The expansion of renewable energy is creating attractive investment opportunities in flexible and dispatchable assets within the power system, with battery energy storage system (BESS) being the preferred technology given their scalability and cost efficiency. Early market entrants can benefit from first-mover advantages, but long-term success requires expertise and a nuanced strategy to address challenges like price saturation and revenue compression as the sector evolves.
- **Battery storage maximises value through revenue stacking and business models:** Grid-scale BESS projects generate value by offering multiple grid services as renewable energy penetration grows. Business models like tolling, regulated cost recovery, and merchant approaches help developers balance revenue certainty with market risk.
- **Attractive BESS markets have common features:** These markets tend to have high renewables penetration, growing electricity demand, grid constraints, and retiring thermal generation. Examples are Electric Reliability Council of Texas (ERCOT), California Independent System Operator (CAISO), Australia's National Electricity Market (NEM), and markets in Chile, Italy, and the UK, all benefitting from favourable policies and shifting market structures.

The energy storage market has been fast growing in recent years

The exponential growth in energy storage globally in recent years reflects the rising need for flexible and dispatchable capacity to complement renewable generation. As the share of solar, wind and other variable renewable sources increases, balancing supply and demand and maintaining grid reliability has become more challenging, creating strong incentives for energy storage capacity deployment. Between 2020 and 2024, cumulative global battery storage capacity soared from just 12 gigawatt-hours (GWh) to over 176 GWh, achieving a remarkable compound annual growth rate (CAGR) of 95% (Figure 1). Lithium-ion batteries have powered most of these deployments, thanks to their versatility and cost-effectiveness, largely driven by economies of scale and technology improvement resulting from their widespread adoption in electronic devices and the electric mobility sector.

Figure 1:
Battery storage capacity deployment has accelerated in recent years



Source: BloombergNEF (BNEF), "1H 2025 Energy Storage Market Outlook", April 2025.

Different types of battery energy storage system projects

BESS projects are typically built under three project types: stand-alone grid-scale, co-location with generation assets like wind or solar farms, and virtual power plants (VPPs) which are connected to the distribution network and aggregate multiple small-scale projects to act as a dispatchable unit (Figure 2).

Figure 2:
Three primary energy storage project types

Stand-alone grid-scale	Co-located with generation (e.g. solar, wind or gas)	Distributed / virtual power plants (VPPs)
• Flexible capacity only (no generation), or able to operate independent of generation • Connected to the distribution or transmission network, usually behind a dedicated grid tie[1] • Large-scale projects (multi-megawatt) • Contracted and uncontracted revenue opportunities across regulated and deregulated markets	• Hybridizes renewable generation with flexible storage capacity • Both renewable generation and storage are operated in a manner that places limitations on how the flexible capacity is operated • Large-scale projects (multi-megawatt)	• Stand-alone or co-located energy storage with generation and/or building load management • Connected behind residential, commercial and industrial customer utility meters • Aggregates hundreds or thousands of small (low or sub-megawatt) individual projects to operate as a single large 'virtual' power plant

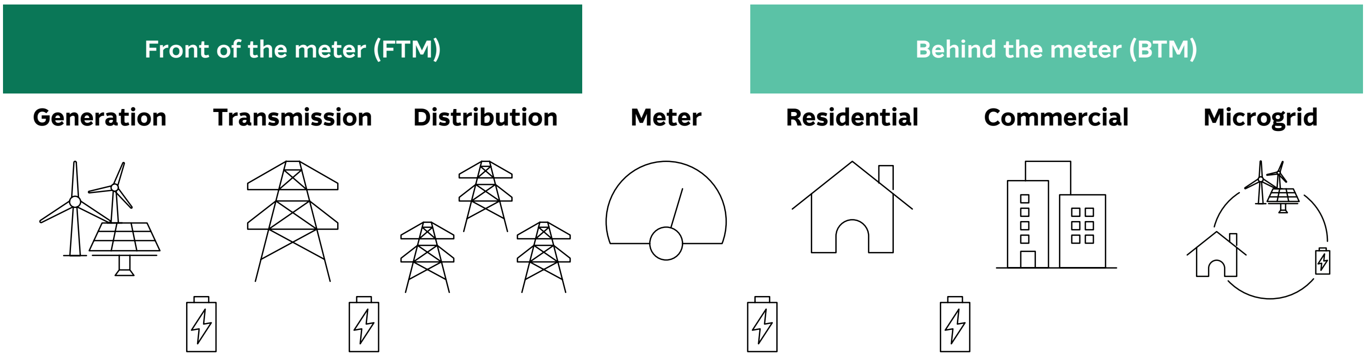
Source: Macquarie Asset Management analysis.

1. A grid tie connects battery to the grid, enabling the battery to charge from and discharge to the grid.

Projects may be grid-tied directly to the network or may also be hosted at a customer's site to help moderate their load. These configurations are broadly categorised as either front-of-the-meter (FTM) or behind-the-meter (BTM) (Figure 3). BTM systems operate on the customer's side of the meter, primarily serving on-site loads. These solutions are typically deployed to reduce a customer's energy bills through strategies such as time-of-use shifting and peak demand reduction. They can also help improve resilience.[2]

In contrast, FTM systems are connected directly to the transmission or distribution grid and are designed to deliver services to the wholesale market and the grid. These systems – particularly stand-alone grid-scale BESS – are designed to capitalise on multiple revenue streams across capacity, wholesale power and ancillary service markets. Bidding strategies that look to optimise revenue across all available market products are often referred to as 'revenue stacking', allowing developers and operators to realise more economic value than just bidding a single product. The remainder of this paper focuses on FTM stand-alone grid-scale projects.

Figure 3:
Front-of-the-meter (FTM) and behind-the-meter (BTM) solutions



Sources: Battery Council International, "Behind the Meter Energy Storage: Advancing Towards Net-Zero Carbon Energy Production", May 2024.

BESS has wide-ranging revenue streams and business models

As summarised in Figure 4, BESS revenue streams encompass wholesale market activities, contractual availability payments, and a range of system support functions. For FTM stand-alone grid-scale projects, the value proposition lies in combining multiple distinct revenue opportunities into a coherent operating strategy, and their three main revenue streams are: (1) energy trading, (2) capacity mechanisms, and (3) ancillary services.

Energy trading. Battery storage facilities can generate arbitrage revenues from day-ahead, intraday and real-time power markets by charging the battery when electricity prices are low and discharging when prices are high. Arbitrage revenues can derive from the wholesale market, which typically is procured a day or more in advance to meet forecasted demand. Variations between forecasts and actual renewable output can create additional opportunities in real-time trading – including the intraday market and, in the UK, the balancing mechanism[3] – where price spreads are often wider than in the day-ahead market.[4] The significance of arbitrage revenues generally increases within a market over time as returns from ancillary services decrease due to price cannibalisation as additional capacity is introduced. To assess a battery project, one typically develops an outlook on the day-ahead market and then considers how much additional value can be secured from real-time energy and ancillary service opportunities across the targeted timeframe.

2. Battery Council International, "Behind the Meter Energy Storage: Advancing Towards Net-Zero Carbon Energy Production", May 2024.
3. The UK Balancing Mechanism is National Grid ESO's real-time market, which operates after the intraday market closes.
4. Modo Energy, "Intraday trading: what is the revenue potential for batteries?", December 2023.

Capacity mechanisms. The capacity market functions as a forward reliability mechanism, securing adequate dispatchable capacity to meet peak demand and maintain system stability, especially during contingency events and periods of low renewable generation. In CAISO's[5] Resource Adequacy program and the UK's National Grid Electricity System Operator (ESO) capacity market, this is achieved by contracting resources, including BESS, to ensure sufficient capacity availability. Payments are tied to their committed capacity, with penalties imposed for non-performance.

Ancillary services. Ancillary services are the operations outside the core functions of generation and transmission that enable grid operators to maintain grid stability and reliability. There is a spectrum of these services, but the major ones are reserves and frequency regulation.[6]

Reserves are BESS that are procured to stand in waiting for deployment during a contingency event, such as a generator fault and transmission outage. Reserve services are usually further divided into subcategories based on their response time. For instance, ERCOT[7] procures three reserve products, including Responsive Reserve Service (RRS), ERCOT Contingency Reserve Service (ECRS) and Non-spinning, which respectively refer to capacity that can ramp within 0.25-1 minute, 10 minutes and 30 minutes.[8] Frequency regulation, on the other hand, ensures the real-time balance of supply and demand by maintaining grid frequency within the standard operating range. This is achieved by continuously adjusting the instantaneous balance of load and supply – either injecting power into the grid (regulation up) or drawing power from it (regulation down).

Beyond reserves and frequency regulation, BESS can also deliver a range of other critical grid services. Examples include:

- Black start (also known as restoration), which enables the grid to restart following a total or partial shutdown without relying on external power sources
- Reactive power management, or voltage control, which regulates the flow of reactive power to maintain voltage levels and support efficient power transmission
- Virtual or synthetic inertia, a service that leverages the BESS's power electronics and control algorithms to emulate the inertia-like response typically provided by conventional synchronous generators

Figure 4:
BESS has a variety of possible revenue streams

Energy trading

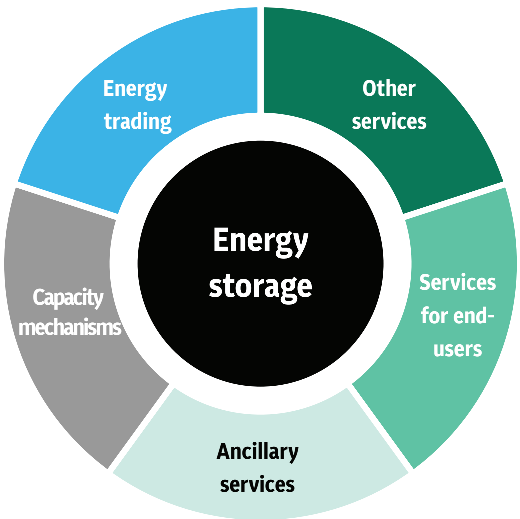
Charging the battery when electricity prices are low and discharging when prices are high to profit from price differences in the wholesale power market

Capacity mechanisms

BESS providers are rewarded for maintaining availability to ensure sufficient system capacity during peak demand

Ancillary services

Services where the battery contributes to maintain the functioning of the electricity transmission grid within the appropriate standards



Other services

Including transmission and distribution (T&D) deferral, congestion relief, and renewable integration, among others

Services for end-users

(BTM batteries only)
Services provided to directly benefit end-users, e.g. time-of-use bill management

Sources: Rocky Mountain Institute (RMI), "The Economics of Battery Energy Storage", October 2015; Ernst & Young (EY), "Four factors to guide investment in battery storage", June 2024; Macquarie Asset Management analysis.

5. CAISO operates California's wholesale power grid.
6. New Energy States Committee on Electricity, "Ancillary Services Primer", September 2017.
7. ERCOT is the operator of Texas's electrical grid.
8. Modo Energy, "ERCOT's Ancillary Services: a beginner's guide", December 2024.

The ability to 'value stack' by bidding across various market products is highly dictated by market-specific participation rules. For example, ERCOT and CAISO are both grids within the US but have different stacking opportunity sets, as shown in Figure 5.

Figure 5:
The set of revenue stacking opportunities varies across different grids and power markets

Services	ERCOT	CAISO
Energy trading	• Day-ahead trading • Real-time trading	• Day-ahead trading • Real-time trading
Ancillary services (reserves and frequency regulation)	• Responsive Reserve Service (RRS) • ERCOT Contingency Reserve Service (ECRS) • Non-spinning reserve • Regulation up/down	• Spinning reserve[9] • Non-spinning reserve[10] • Regulation up/down
Capacity mechanisms	• N/A	• Resource adequacy

Sources: CAISO, "2023 Special Report on Battery Storage", July 2024; Modo Energy, "ERCOT's Ancillary Services: a beginner's guide", December 2024; Macquarie Asset Management analysis.

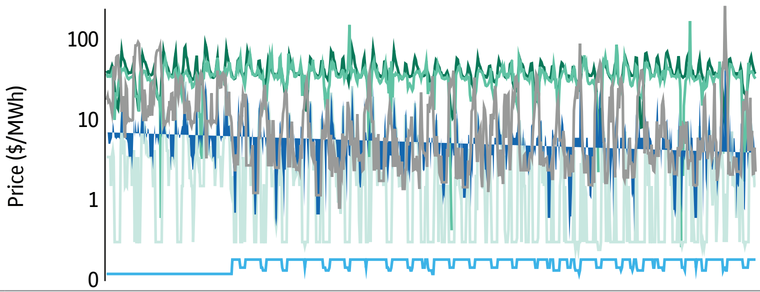
For developers and investors, the strategic challenge lies not only in identifying potential revenue streams but also in evaluating how these streams may evolve and what risks may emerge over the asset's lifetime. Much of the success of a battery storage project is determined in the planning period – it depends on how well the developer can assess (1) market evolution over time, (2) what contracting options may be available to manage risk and improve returns, and (3) what the optimal operation strategy is for a given market. This is a complex undertaking, as it involves navigating trade-offs: the highest immediate revenues may not necessarily translate into the greatest long-term profitability. For instance, frequent cycling (charging and discharging) of the battery can boost short-term earnings but accelerates degradation, ultimately shortening the battery's lifespan.[11] To address these complexities, sophisticated techno-economic tools are often employed. These tools simulate bidding behaviour across multiple market products, incorporate market-specific bidding rules, and account for the technical constraints of the battery. Figure 6 illustrates a monthly energy storage dispatch simulation for a hypothetical project within the CAISO market.

9. In the context of CAISO, spinning reserve is standby capacity from generation units already connected or synchronised to the grid and that can deliver their energy in 10 minutes when dispatched.
10. In the context of CAISO, non-spinning reserve is capacity that is not synchronised to the grid but can be synchronised and ramped to a specified load within 10 minutes.
11. Modo Energy, "Degradation and cycling: how it affects your battery", March 2023.

Figure 6:
Example of operational optimisation – monthly energy storage dispatch simulation in CAISO (January 2020)

1. Market prices[12]

Analyse CAISO hourly average prices for real-time (RT) and day-ahead (DA) energy, reserve and regulation product prices at node ALTAPES_7_N001[13]

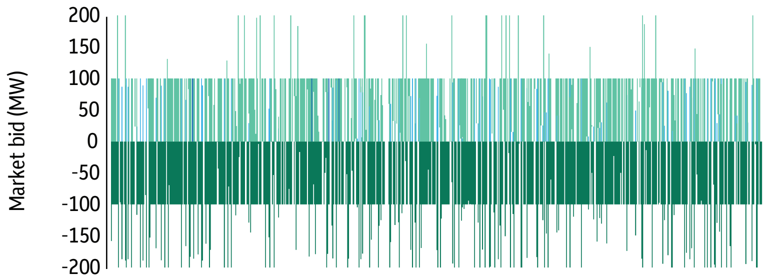


CAISO products

- Day-ahead energy
- Real-time energy
- Spinning reserves
- Non-spinning reserves
- Regulation up
- Regulation down

2. Bid optimisation[14]

Bid dispatch simulation based on market prices, CAISO market participation rules and 100 megawatts (MW) | 200 MWh Powin 230 BESS technical specification.

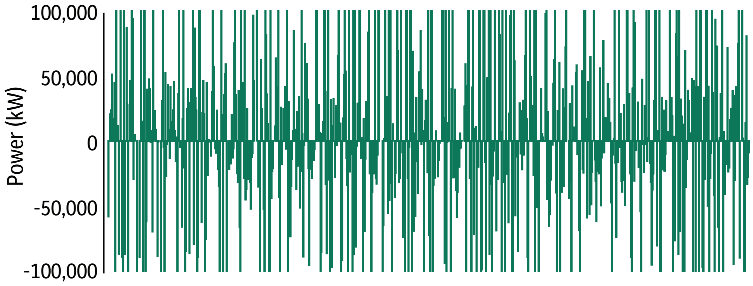


Bid breakdown

- Regulation down - 50.3%
- Regulation up - 31.1%
- DA energy - 11.2%
- RT energy - 6.8%

3. Net power flow simulation

Evaluate power flow at the grid interconnection point: (+) battery is discharging, (-) battery is charging. The simulation accounts for efficiency losses.

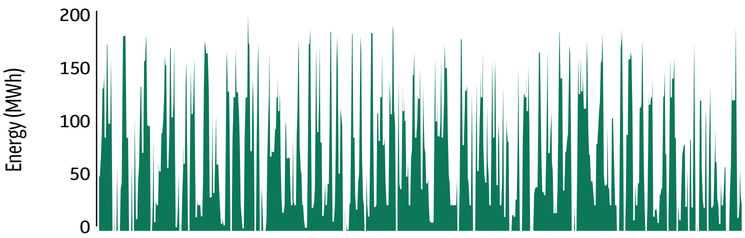


Charging and discharging

- Charging – 18.5 GWh
- Discharging – 16.2 GWh
- Efficiency loss – 2.3 GWh

4. State of charge

Simulate the state of charge (SOC) of BESS to estimate battery degradation as a function of utilisation.

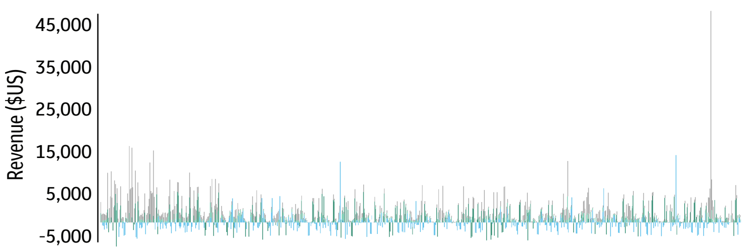


BESS technical performance

- Average SOC – 49%
- BESS degradation – 0.6%/month

5. Revenue

Hourly forecast of storage revenue by CAISO product. This is used to benchmark total monthly revenue.



Monthly revenue

- Total – $US1.27m
- Per power – $US12.73/kilowatt (kW)
- Per energy – $US6.37/kilowatt-hour (kWh)

Source: Macquarie Asset Management analysis. This example is for informational purposes only and is intended to illustrate a hypothetical application of an energy storage asset in CAISO for the month of January 2020. Based on historical performance and therefore are not suitable for forward-looking interpretation. Past performance is not indicative of future returns. For illustrative purposes only.

12. Historical price curves reported on the CAISO OASIS database.
13. Node ALTAPES_7_N001 is the node of the Pomona Alta Gas BESS, which has been operational in California since 2017.
14. Perfect-foresight dispatch co-optimisation results for the Macquarie Asset Management internal model.

The choice of business model for BESS projects is fundamentally driven by revenue risk considerations. The spectrum of business models (Figure 7) reflects a delicate trade-off between revenue certainty and exposure to market volatility. Low-volatility models, like pure tolling and regulated cost recovery, offer stable cash flows but limit flexibility and upside potential. Conversely, pure merchant strategies maximise returns in volatile markets but carry significant revenue risk, often requiring hedging or revenue insurance. Meanwhile, intermediate models, such as floor-plus-share,[15] combine a guaranteed baseline revenue with opportunities for market participation, offering a blend of security and flexibility.

The effectiveness of any chosen model hinges on accurate forecasting of market trends and the ability to adapt dispatch and contracting strategies over time. Ultimately, the optimal business model depends on factors such as the developer's risk tolerance, financing requirements, and expectations for market evolution. In practice, the most resilient projects often integrate elements from multiple models, ensuring a stable cash flow foundation while retaining the flexibility to capitalise on emerging market opportunities.

Figure 7:
Different energy storage business models have different market volatility exposure

Model	Description and key features	Revenue characteristics
Pure tolling	Owners lease the asset to a third party, transferring dispatch rights in return for fixed revenues. Asset owners retain ownership but give up operational control.	Fixed revenue stream regardless of market conditions.
Rate-based cost recovery	T&D operators own energy storage as grid assets, providing services and recovering costs through regulated cost-based rates.	Regulated cost recovery ensures stable returns; market-based rate services may also be used if compliant with regulations.
Contracted revenue	Asset owners secure long-term contracts with offtakers, such as power purchase agreements (PPAs) or capacity-based payments. Asset owners retain dispatch and capacity rights under auction-based contracts.	Stable, predictable revenue stream over the contract tenor.
Floor-plus-share	In this hybrid model, optimisers (e.g. trading firms) guarantee a revenue floor and share profits above it, blending features of merchant and tolling models, akin to one-way contract-for-difference (CfD) structures.	Minimum guaranteed revenue or profit with additional upside potential. Optimisers cover shortfalls if revenues fall below the threshold.
Pure merchant	Owners charge/discharge electricity based on price signals in competitive markets, often using optimisers who share profits.	Revenue depends on price volatility. Owners benefit from price swings but also face downside risk. Revenue insurance may be used to mitigate risks.

Sources: BNEF, "Energy Storage Tolling: A Primer", March 2025; Macquarie Asset Management analysis.

15. A hybrid model where optimisers guarantee a revenue floor and share profits above it. See Figure 7 for more details.

Market dynamics and policy shifts are shaping energy storage investments

Markets attractive for BESS typically exhibit a combination of the following factors: (1) increasing renewable energy penetration (which drives intraday power price volatility and heightens system balancing needs), (2) rising power demand, (3) transmission capacity bottlenecks, and (4) declining thermal generation, primarily due to coal plant retirements.

These dynamics create opportunities for both merchant and contracted revenue streams. For instance, in markets where renewable deployment has outpaced grid reinforcement, storage can capitalise on significant arbitrage margins by absorbing surplus generation and discharging during evening peak demand. Similarly, in regions where fossil fuel capacity has retired without adequate replacement, system operators increasingly rely on storage as a capacity resource, generating additional revenue through capacity procurement mechanisms. Nonetheless, market entry timing is crucial. Early entrants can capitalise on high returns fuelled by volatile price spreads and undersupplied ancillary markets. However, as installed storage capacity grows and surpasses demand for these services, reduction in revenue typically ensues.

ERCOT (Texas, US)

ERCOT, one of the most developed BESS markets globally, is a prime example of the market evolution described above. In recent years, extreme weather events and grid instability – exacerbated by the rapid expansion of renewable power capacity and surging electricity demand from data centre and cryptocurrency mining in Texas – have created exceptional opportunities for both energy trading and ancillary services. As a result, BESS capacity within the ERCOT market has grown exponentially, rising from 1,473 MWh in 2021 to 13,736 MWh in 2024, a more than ninefold increase in just three years (Figure 8).[16]

By 2024, however, declining power price volatility and the saturation of ancillary markets had eroded average revenue. The volume-weighted average clearing price of ancillary service in 2024 was $US7.03 per MW per hour, which is only a third of the average in 2022 and 2023 (Figure 9).[17] At the same time, the ERCOT market faced additional headwinds from US trade policies, including tariffs on batteries imported from China and other Asian countries. These measures have increased the investment cost of BESS projects across the US.

Despite these challenges, persistently rising electricity demand and continued deployment of non-dispatchable renewable energy sources are expected to sustain elevated power price volatility in the near term, ensuring that ERCOT remains a key market for BESS.

Figure 8: Cumulative battery capacity within the ERCOT market has grown by more than ninefold from 2021 to 2024

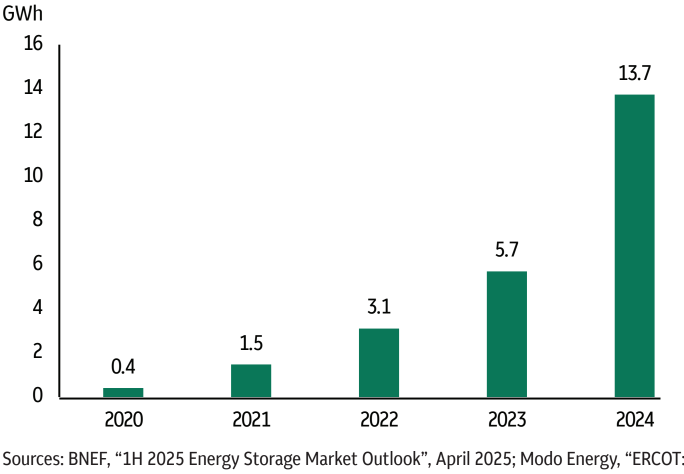
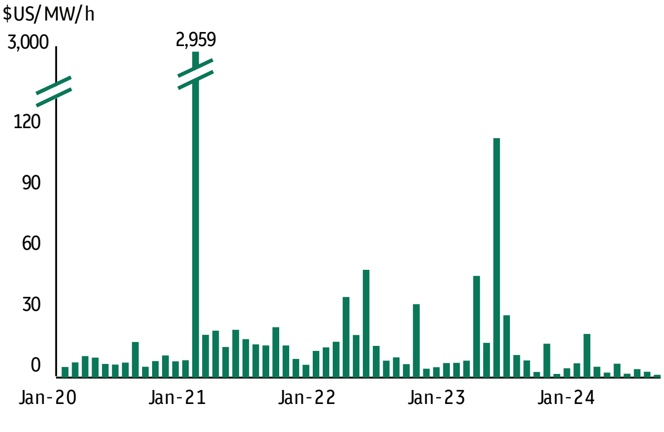


Figure 9: Lower energy market volatility and rising battery participation drive declining ancillary service prices in ERCOT in 2024



Sources: BNEF, "1H 2025 Energy Storage Market Outlook", April 2025; Modo Energy, "ERCOT: How did power prices evolve in 2024?", February 2025.

16. BNEF, "1H 2025 Energy Storage Market Outlook", April 2025. Figures exclude pumped hydro capacity.
17. Modo Energy, "ERCOT: How did power prices evolve in 2024?", February 2025.

CAISO, NEM and Chile are also popular BESS markets, thanks to high renewable penetration and grid constraints that create sustained arbitrage and ancillary opportunities. European markets such as Italy and the UK are also showing growing potential.[18]

CAISO (California, US)

CAISO is also a relatively well-developed market for BESS. It is attractive for investment not only for its high solar penetration and relatively well-established market framework but also for its long-term resource adequacy contracts. These contracts offer stable revenue streams and currently comprise the majority of income for most BESS participants.[19] Although the market is increasingly competitive – with capacity additions projected to be nearly 14 GWh this year[20] – the ongoing demand for BESS to enhance grid stability and facilitate renewable energy integration continues to present significant opportunities for developers.

NEM (Australia)

Australia presents a compelling case for battery investment as structural shifts in the National Electricity Market (NEM) create pricing volatility and multiple revenue streams. The phase-out of coal-fired generation, coupled with a rapid build-out of wind and solar, has heightened grid instability.[21] As a result, batteries are increasingly essential to maintain system reliability. The trend is expected to continue, driven by robust policy support – such as the Capacity Investment Scheme, which guarantees long-term returns for large-scale battery storage and renewables – and increasing deployment needs as variable renewable energy continues to grow.[22] These factors sustain high price volatility, further reinforcing the economic case for BESS investment.

Chile

Chile offers strong fundamentals for battery investment, driven by rapid solar deployment and persistent transmission bottlenecks between generation rich northern regions and southern demand centres.[23] These constraints have intensified intraday price volatility and curtailment, creating strong arbitrage opportunities for storage. The market's marginal cost-based pricing allows BESS to monetise both energy shifting and capacity value. These conditions are likely to persist (albeit somewhat mitigated by the growing deployment of BESS) until at least 2032, when significant transmission upgrades are anticipated to come online, enhancing the visibility of returns.[24]

Europe

The European market is also demonstrating growth potential in the energy storage sector, with recent policy developments in Italy and the UK paving the way for increased investment in battery storage. Italy has introduced the Italian Energy Storage Capacity Procurement Mechanism (MACSE), which will hold its inaugural auction in September 2025. This auction, targeting delivery by 2028, will award 15-year capacity payments indexed to inflation, creating a stable revenue stream for investors.[25] In the UK, the Clean Power 2030 Action Plan targets to generate as much clean energy as it consumes by 2030.[26] This initiative promotes the expansion of renewable energy sources and in turn increases the demand for flexible solutions including BESS. These policy shifts, combined with existing grid instability caused by high renewable energy penetration, are expected to enhance the economic viability of battery storage projects in both markets, making them increasingly attractive to developers and investors.

18. IDTechEx, "Countries With Soon-to-Boom Li-ion Battery Energy Storage Systems (BESS) Markets", December 2024.
19. Modo Energy, "Resource Adequacy: How it works, how you're paid, and how to apply", December 2024.
20. BNEF, "1H 2025 Energy Storage Market Outlook", April 2025.
21. Modo Energy, "Australia: The 2025 NEM Battery Energy Storage Pipeline Report", May 2025.
22. Department of Climate Change, Energy, the Environment and Water, Australia, "Capacity Investment Scheme", August 2025.
23. National Bureau of Economic Research, "The Dynamic Impact of Market Integration: Evidence from Renewable Energy Expansion in Chile", May 2022.
24. Aurora Energy Research, "Chile: Aurora's nodal model sees curtailment pressures easing by 2027 with support from storage and transmission upgrades", July 2025.
25. Timera Energy, "Italy's 1st MACSE auction: green light for BESS investors", March 2025.
26. Department for Energy Security & Net Zero, United Kingdom, "Clean Power 2030 Action Plan: A new era of clean electricity – main report", April 2025.

Conclusion

Battery storage plays a pivotal role in building a sustainable, resilient energy future. With increasing renewable energy penetration, rising electricity demand, and grid instability, BESS provides versatile solutions to balance supply and demand, ensure system reliability, and unlock diverse revenue streams. BESS markets like CAISO, ERCOT, and NEM, as well as markets in Chile and some European countries (Italy and the UK), demonstrate strong investment potential driven by policy and market dynamics. Yet, challenges like market saturation as the sector matures and operational trade-offs call for sophisticated strategies to optimise both short-term gains and long-term value. Developers and investors that adapt effectively will be best positioned to capitalise on the economic opportunities within this transformative industry.

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Contact us by region

Americas

Fifth Avenue
New York
212 231 1000
mim.americas@macquarie.com

Australia

Elizabeth Street
Sydney
1 800 814 523
miminstitutionalclients@macquarie.com

EMEA

Ropemaker Place
London
44 20 303 72049
mamclientservice.emea@macquarie.com

Asia

Harbour View Street
Hong Kong
852 3922 1256
macquarie.funds.hk@macquarie.com