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Unlocking value in battery storage

OPINION PIECE. PLEASE SEE IMPORTANT DISCLOSURES IN THE ENDNOTES.

Francesco Cacciabue, CFA®

Global Head of Clean Energy Investments, Nuveen Infrastructure

Geoff Hoffheinz

Chief Engineer, Clean Energy, Nuveen Infrastructure

The growing role of energy storage in grid infrastructure

Energy storage is now integral to the evolution of modern grid infrastructure, its rapid rise driven by the transition to renewables and increasing electrification. Batteries are central to clean energy transitions, underpinning COP28 goals to triple renewable capacity by 2030, double energy efficiency improvements, and accelerate the shift away from fossil fuels.

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Battery storage growth has surged in recent years, led by China, the EU and the U.S. Global battery capacity has doubled year-on-year, with BloombergNEF predicting record deployment in 2025 — 23% higher than in 2024.[1] There are some challenges to the growth of this sector, with manufacturing and material supply chains concentrated in a few countries. However, advances in technology and legislation, such as the EU's Net Zero Industry Act, aim to support manufacturing and deployment.

Looking ahead, more than 80% of global battery energy storage system (BESS) demand is expected to come from utility-scale projects, which are critical for managing the grid as fossil fuels are phased out. Costs of BESS have also dropped by 90% in under 15 years, falling sharply since 2022.[2]

Market drivers and policy landscape

The rapid growth of battery storage is shaped by financial incentives, regulatory requirements and strategic investment. Tax credits, grants, and mandates to pair storage with renewables, are accelerating deployment. Power companies are increasingly integrating batteries into longterm planning. Meanwhile, developers are building standalone systems or combining storage with wind and solar.

In the EU, with the Net-Zero Industries Act (June 2024), strategic projects involving net zero technologies are given priority status, allowing shorter permitting and approval timelines, and a reduced administrative burden. This helps large-scale battery developers move faster.[3] It also enables the creation of 'net-zero acceleration valleys' — geographic zones for clusters of clean-tech manufacturing (including battery storage) to benefit from concentrated infrastructure and facilitation.[4]

Defining utility scale battery storage

Utility-scale battery storage consists of large, grid-connected battery systems built to store and deliver electricity at levels needed for the wider power grid.

In the U.S., the Clean Electricity Investment Tax Credit (CEITC) is now the main federal tax incentive for commercial and utility-scale battery storage, providing a base credit of 6% of the eligible project cost. It also allows for a bonus credit of up to 30%, if prevailing wage and apprenticeship requirements are met and there is additional credit available if the project is located in a qualifying energy community.[5]

Key market drivers for further BESS deployment globally include the expansion of nonprogrammable renewables, rising volatility requiring energy shifting, electrification and peak demand management, and the phaseout of fossil flexibility. Supportive regulations, prosumer participation, demand response markets, and industrial decarbonization pressures further reinforce the need for large-scale storage solutions.[6]

Battery storage technologies

Battery storage technologies convert chemical energy into electricity and are central to modern energy systems. While lithium-ion batteries currently dominate the market, alternative chemistries such as sodium-ion and flow batteries continue to develop. Each technology offers distinct advantages and limitations, and ongoing innovation continues to reshape the landscape.[7]

Lithium-ion battery systems

The past decade has been defined by lithium-ion batteries, which offer far higher energy density and longer cycle life than older lead-acid or nickel-cadmium systems. Specific energy ranges from 90–300 Wh/kg, compared to 35–40 Wh/kg for lead-acid. Their compactness and efficiency have made lithium-ion batteries the backbone of electric vehicles (EVs). There is ongoing R&D into lithium-ion batteries, focused on improving energy density, charging times, safety and durability. Battery pack prices have fallen dramatically, from USD 800/kWh in 2013 to a record low USD 108/kWH in 2025,[8] though costs remain sensitive to mineral price volatility. Lithium iron phosphate (LFP) chemistries now account for the majority of storage applications, representing 91% of the market in 2025, due to lower costs and longer life cycle. Lithium-ion are expected to remain the leading short-duration storage technology (≤8 hours), though recycling and second-life applications (such as repurposing EV batteries) are critical to reducing their carbon footprint.[9]

Sodium-ion batteries

Sodium-ion batteries are gaining traction as a lower-cost alternative to lithium-ion batteries, using abundant sodium resources and fewer critical minerals. Renewed interest stems from advances in hard carbon anodes and concerns over lithium availability. Production capacity could reach 70 GWh annually by 2025 and nearly 400 GWh by 2030.[10] Sodium-ion batteries are less energy-dense than lithium-ion batteries, but potentially 20-30% cheaper if scaled comparably. Although there are some technical challenges to overcome, these chemistries are predicted to play a key role in BESS. One driver for this is the prospect of building new supply chains that are less reliant on China, which currently manufactures around 80% of the world's lithium-ion batteries.[11]

Flow battery technologies

Flow batteries, particularly vanadium redox systems, look promising for long-duration storage. They store energy in liquid electrolytes housed in separate tanks, allowing energy and power to be scaled independently. This design avoids degradation from prolonged high states of charge, a challenge for lithium-ion and sodium-ion batteries. Flow batteries are relatively mature but face supply chain constraints. Scaling will depend on market signals and regulatory frameworks that incentivise longer-duration storage.[12] However, there are environmental concerns over the large amounts of vanadium solutions that are required to be held in tanks onsite.

Emerging and alternative technologies

Beyond lithium-ion and sodium-ion batteries, other chemistries are being explored for multi-day storage. Iron-air batteries demonstrate potential for long-duration applications. However, most markets currently incentivize short-duration systems (≤4 hours), limiting uptake. Alternative chemistries may become viable if regulatory frameworks evolve to reward longer storage durations.[13]

Technology comparison matrix

There are trade-offs in cost, energy density, cycle life, and scalability when comparing different technologies. LIBs dominate short-duration storage, while flow and iron-air batteries may serve longer durations. Sodium-ion batteries offer cost advantages but lower energy density.

Duration and power requirements by application

Battery technologies must align with application needs. Short-duration systems (≤4 hours) dominate today's markets, driven by reserve and capacity requirements. However, demand for longer-duration storage is rising, with the number of 8-hour systems increasing to meet market requirements. Value stacking – using batteries for multiple services – can improve economics but this can add complexity, accelerate degradation, and complicate revenue forecasting. Systems optimized for short-duration services may underperform in long-duration roles.[14]

Innovation trends and R&D developments

There is continued innovation not only in battery chemistry, but also in system integration, including battery management systems, inverters and grid connections. R&D is expected to reduce capital costs by up to 40% by 2030, making solar-plus-storage highly competitive with coal and gas. Lower costs are also increasing the adoption of behind-the-meter and mini-grid applications, improving electricity access globally.[15]

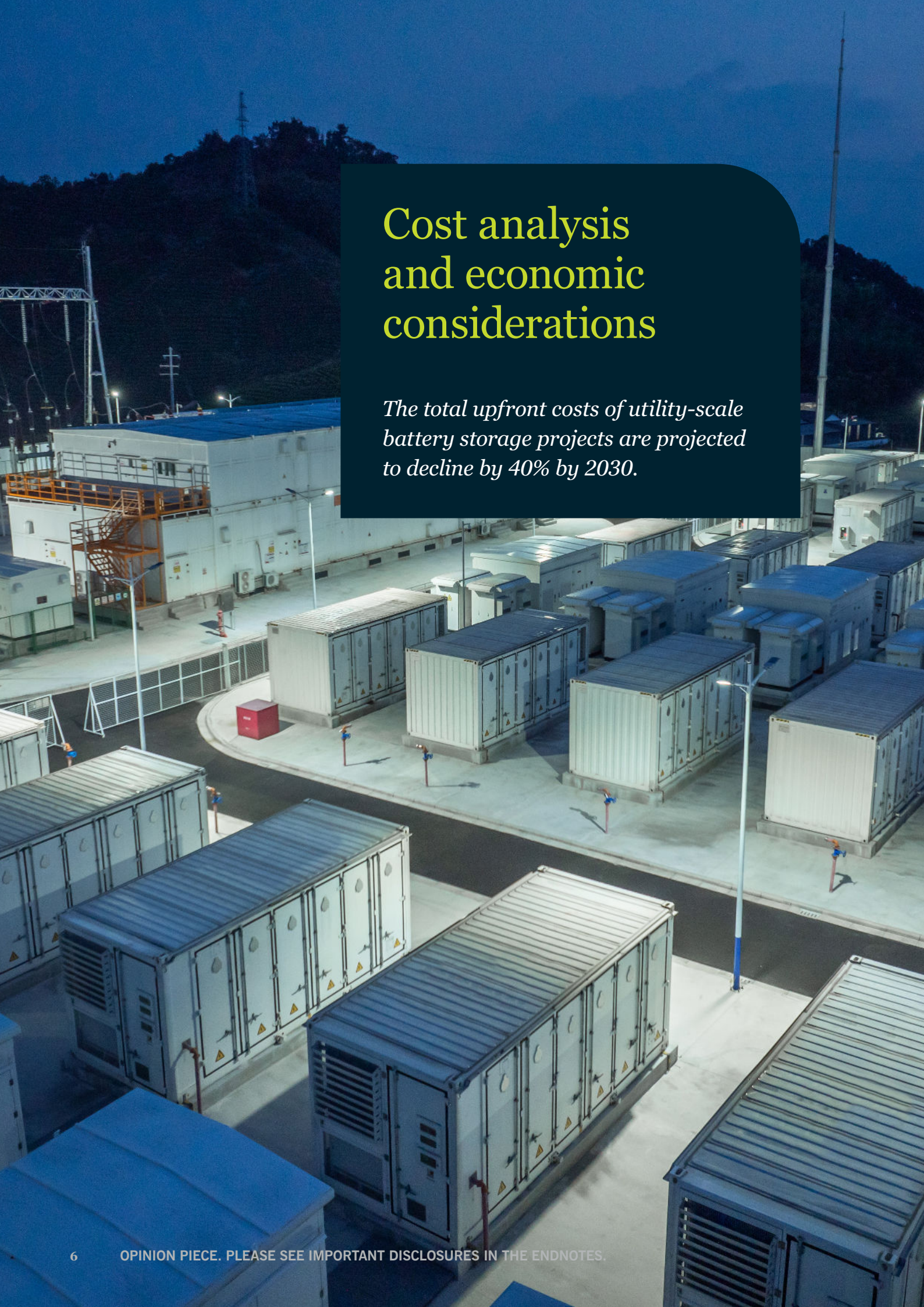
Stand-alone compared to co-located battery storage

Stand-alone BESS operate independently of any generation source and can be strategically placed within the grid. Co-located BESS — storage paired with renewables such as wind or solar PV — benefit from shared infrastructure and synergy with generation, increasing efficiency by smoothing variability, matching supply with demand and reducing curtailment.[16]

The total upfront costs of utility-scale battery storage projects are projected to decline by 40% by 2030. This makes stand-alone battery storage more competitive with natural gas peaker plants (power plants that run only during periods of high electricity demand), and battery storage paired with solar PV one of the most competitive new sources of electricity. With the declining costs of batteries, both stand-alone and co-located applications are now economical in many parts of the world.[17]

"The total upfront costs of utility-scale battery storage projects are projected to decline by 40% by 2030."

BATTERY TYPE	ENERGY DENSITY	COST	CYCLE LIFE	CHARGE/DISCHARGE SPEED
Lithium ion (Li-ion)	High	High	3,000 – 10,000	Fast
Lead-acid	Low	Low	500 – 2,000	Slow
Sodium-based	Medium	Medium	3,000 – 5,000	Medium
Flow batteries	Low	Medium	10,000+	Slow
Nickel-based	Medium	Medium	2,000 – 5,000	Medium
Hydrogen fuel cells	High	Very high	Unlimited (depends on fuel)	Slow
Zinc-air	Medium	Low	500 – 2,000	Slow
Supercapacitors	Low	Medium	1,000,000+	Utra-Fast
Solid-state	High	Very high	10,000+	Fast



Cost analysis and economic considerations

The total upfront costs of utility-scale battery storage projects are projected to decline by 40% by 2030.

Capital expenditure (CapEx) trends

The global battery market value is projected to quadruple by 2030, from USD 120 billion today to nearly USD 500 billion in the Net Zero Emissions (NZE) scenario.[18] Global investment in energy storage reached USD 54 billion in 2024, a 73% increase over 2022/23 averages and more than eleven times 2019/20 levels. China accounted for 40% of investment in 2024, adding 84 GWh of capacity, supported by colocation mandates and subsidies. The U.S. followed with 29%, driven by Inflation Reduction Act incentives, while Germany contributed 11%. Developing economies such as Chile, India, the Philippines, and South Africa doubled investments, though they remain a small share globally.[19]

Operating expenditure (OpEx)

While investment in BESS deployment often focuses on upfront capital expenditure, its important that operational costs are not overlooked. Battery lifespans can be shorter than other components and highly sensitive to cycling, depth of discharge and temperature. Robust battery management systems can mitigate these risks but require careful design.[20]

Levelized cost of storage (LCOS)

LCOS varies by region, system characteristics and regulatory environment. Costs have fallen sharply since 2022, with reductions of 30 – 40% in one year due to lower raw material prices, expanded Chinese cell manufacturing and standardized system integration. Strong competition has further driven down costs.[21]

Revenue streams and value stacking

Batteries generate revenue through multiple applications, often simultaneously. Value stacking can improve economics, but also add complexity.[22] [23]

- **Energy shifting and arbitrage:** Utility-scale batteries store surplus renewable power, reduce curtailment, and provide peaking capacity. In competitive markets, they monetize price spreads by charging at low prices and discharging at high prices.
- **Frequency regulation and ancillary services:** Batteries supply inertia, voltage control, reserves, and black start capabilities. In Europe, reforms have enabled batteries to dominate frequency response markets. Ancillary services drive around 15% of new deployments annually.
- **Capacity markets:** A capacity market is a mechanism used by some electricity systems (the UK, parts of the U.S. and some EU jurisdictions) to ensure there is enough available power to meet peak demand in the future. Generators, storage, or demand response providers are paid for being available during future system peaks.
- **Tolling agreements:** These are long-term contracts where the battery asset operator sells the operational rights of the battery to a counterparty for a fixed fee, usually a utility, retailer or large energy trader. This structure can provide investors with more predictable cash flows, by shifting market operations to the off-taker.[24]
- **Power purchase agreement (PPA):** The battery owner or operator sells energy, capacity, or dispatchable services to a counter-party (typically a utility, retailer, or corporate offtaker). PPAs provide long-term, contracted revenue in exchange for the buyer receiving stable, dependable energy or flexibility services.
- **Transmission and distribution deferral:** When used for congestion management, batteries reduce the need for investment into transmission and distribution networks. They can defer costly grid reinforcements, especially in emerging economies with weaker grids, providing local reliability, as well as black start and islanding capabilities. However, regulatory frameworks often restrict ownership by transmission and distribution operators, requiring third-party contracts.

Financing models and investment structures

Financing and investment structures are built around the revenue streams described above. Lenders and investors evaluate a BESS project's value stack to determine bankability: the more predictable and diversified the revenue, the easier it is to finance.[25] Financial incentives, including tax credits, grants, and colocation mandates, continue to drive deployment of BESS. Innovative financing models, such as PayGo, are making off-grid solar-plus-storage systems more accessible, displacing diesel generators.[26]

Cost projections through 2030 and beyond

The electricity storage market will likely see varied growth across different applications and technologies. Future cost trajectories will depend on raw material prices, manufacturing scale, and innovation. Cost reductions are crucial for BESS projects to remain competitive in a challenging environment.

The costs of various battery technologies are projected to decrease significantly by 2030, enhancing their economic viability.

- Lithium-ion battery costs could fall by 54 – 61%.
- Flow batteries may see a two-thirds reduction in total installed costs.
- High-temperature sodium sulphur and sodium nickel chloride batteries could reduce costs by 56 – 60%[27]

Storage additions saw record-breaking growth in 2025 with 315 GWh in annual additions, a nearly 50% jump year-over-year, excluding pumped hydro.[28] A compound annual growth rate of 14.7% is expected to follow, through to 2035, with annual additions reaching 220 GW/972 GWh that year.[29] Overcoming challenging policy shifts and 'tariff turmoil', the two largest markets — China and the U.S. — continue to grow. Annual deployments are also set to scale in Germany, the UK, Australia, Canada, Saudi Arabia and Sub-Saharan Africa.[30]

Global deployment: country by country analysis

Battery storage deployment has accelerated dramatically over the past five years, concentrated in China, the European Union and the United States.[31] *These regions have dominated due to supportive policies, large markets and strong investment flows, but other countries are also beginning to scale up.*

United States

The U.S. is the second largest battery storage market, nearly doubling year-on-year. Utility-scale projects account for 90% of additions, concentrated in California, Texas and the south west. Market reforms, falling costs, and the Inflation Reduction Act's investment tax credit, gave the sector a boost and the new Clean Electricity Investment Tax Credit (CEITC) continues as an incentive. More recent high tariffs on imports are driving up battery prices and slowing development, necessitating the renegotiation of supply contracts, and some projects being delayed or cancelled. However, despite policy changes and uncertainty, developers are still continuing to push forward with ever-larger projects.[32]

Australia

Australia added 1.3 GW of capacity in 2023, more than 2.5 times the previous year. Utility-scale projects made up 60%, driven by wholesale market price spreads and high ancillary service prices. Behind-the-meter adoption also grew, supported by incentives for pairing PV with batteries. Akaysha, acquired by BlackRock, is developing 2.8 GW of projects in Queensland and New South Wales. The Dalrymple battery project (30 MW/8 MWh) in South Australia demonstrates advanced capabilities, providing frequency control, inertia, and short-circuit power to stabilize networks with high renewable penetration.[33]

European Union

In the EU, member states are targeting 45 GW of storage by 2030, supported by reforms such as eliminating double charging and introducing longterm remuneration mechanisms.[34]

The Net-Zero Industries Act (June 2024) has allowed strategic projects involving net zero technologies to be given priority status, meaning shorter permitting and approval timelines, and a reduced administrative burden. This helps large-scale battery developers move faster.[35] It will also enable the creation of 'net-zero acceleration valleys' — geographic zones for clusters of clean-tech manufacturing (including battery storage) to benefit from concentrated infrastructure and facilitation.[36]

EU capacity rose 70% in 2023, with nearly 6 GW added. Utility-scale growth is supported by capacity auctions, such as Italy's 2022 auction awarding 1.6 GW for delivery in 2024. Funding through the Innovation Fund and Recovery and Resilience Facility further supports deployment.[37]

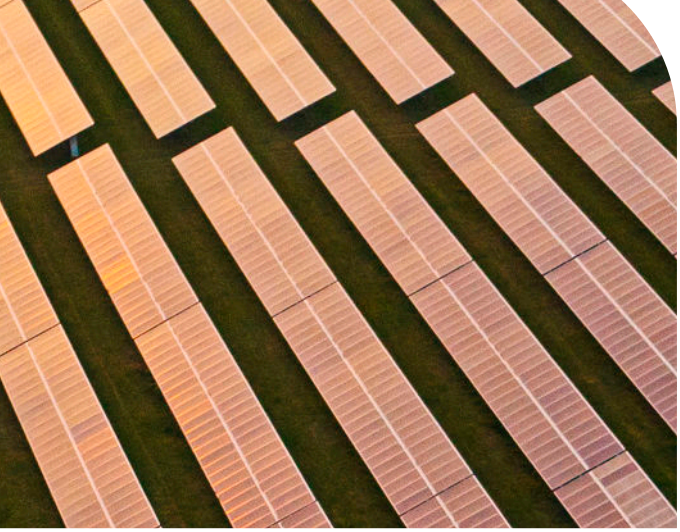
Germany, Italy, and Spain are central to EU deployment. Germany focuses on reducing balance-of-plant costs to lower LCOS, while Italy has nearly 85 GW of projects in permitting and 300 GW of connection requests. Spain, alongside Sweden and Greece, has introduced reforms to eliminate double charging and provide longterm remuneration mechanisms. In Germany, grid boosters alleviate transmission bottlenecks, reducing reinforcement costs. Developers such as Engie, RWE and Enel are expanding portfolios across Europe and internationally.[38]

United Kingdom

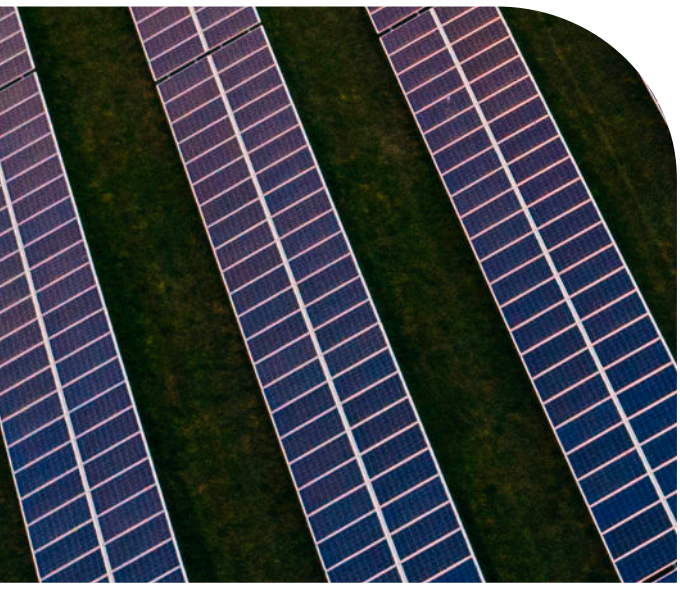
Investment is accelerating in the UK's booming battery storage sector.[39] The UK added over 1 GW of battery capacity in 2023, becoming Europe's largest utility-scale market. Reforms have enabled batteries to access ancillary service markets, with the UK awarding 869 MW of grid-forming storage contracts to provide inertia and short-circuit power. Declining frequency regulation revenues have shifted focus to capacity auctions. Contracted battery capacity is expected to rise from 3.9 GW today to 16 GW by 2027.[40]

Comparative policy and market analysis of battery storage deployment[41]

COUNTRY/ REGION	2023 ADDITIONS	MARKET SHARE/ TOTAL CAPACITY	KEY POLICIES & INCENTIVES	LEADING PLAYERS
China	23 GW (tripled from 2022)	55% of global additions	Provincial mandates to pair storage with renewables; subsidies; time of use tariffs	Multiple Chinese corporations (5 of top 10 globally)
United States	>8 GW	2nd largest globally	Inflation Reduction Act (tax credits, ITC); market reforms	Hecate Energy, NextEra, AES
European Union	~6 GW (+70% YoY)	Target: 45 GW by 2030	Capacity auctions; rooftop PV incentives; EU Innovation Fund	Engie, RWE, Enel
United Kingdom	>1 GW	Largest European utility scale market	Capacity auctions; ancillary service reforms; Pathfinder scheme for inertia/short-circuit power	Engie, RWE, Enel (via EU portfolios)
Australia	1.3 GW (+2.5x YoY)	Utility-scale ~60%	Wholesale market spreads; ancillary service prices; PV pairing incentives	Akaysha (BlackRock)
Japan	>400 MW utility scale; ~300 MW BTM annually	Consistent behind-the-meter (BTM) growth	Subsidies, market reforms	Domestic developers
South Korea	~300 MW utility scale	Market below 2018 peak	Subsidy withdrawal	Domestic developers
India	Emerging market	Significant potential	National storage targets; localisation of production	Multiple domestic developers
Chile	~250 MW utility scale	First large scale deployment in Latin America	Supportive regulation for renewables integration	AES, local developers
Latin America (other)	Small but growing	Early stage	Limited incentives	Various



Grid services and applications



Battery storage systems, both utility-scale and behind-the-meter, are highly versatile assets that provide short-term flexibility and a wide range of grid services. Their ability to shift energy across seconds, minutes, or hours makes them well-suited to balancing supply and demand in systems with a high share of variable renewables. Beyond energy shifting, batteries contribute to ancillary services, system adequacy, and congestion management in transmission and distribution networks.[42]

Utility-scale batteries enhance grid stability by supplying inertia, voltage control, frequency regulation, and fast-starting reserves. Grid-forming inverters allow batteries to support voltage and frequency during disturbances, while black start capabilities enable restoration of service after outages, traditionally provided by diesel generators. Behind-the-meter systems deliver consumer benefits such as backup power, bill reduction through dynamic tariffs, and increased self-consumption of rooftop solar. When aggregated into virtual power plants (VPPs), they can replicate many services offered by larger systems.[43]

Key Applications[44]

- **Renewable integration and firming:** Batteries smooth variability in solar and wind output, supporting reliable supply.
- **Peak shaving and load shifting:** Utility-scale systems provide peaking capacity, charging during low demand and discharging during high demand. In competitive markets, this enables energy arbitrage, monetizing wholesale price spreads.
- **Frequency response and voltage support:** Batteries' rapid responsiveness makes them ideal for ancillary services, including operating reserves and voltage regulation.
- **Black start capability:** While technically feasible, remuneration mechanisms for black start and inertia services remain limited, as these were historically provided free by conventional plants. Pilot projects are testing new frameworks.
- **Transmission congestion relief:** Batteries can defer costly grid reinforcements.
- **Micro-grids and island systems:** Storage supports resilience in localized grids, enabling adaptive islanding during disruptions. Australia and parts of the U.S. have introduced measures to promote micro-grids for critical facilities and disadvantaged communities.

Energy storage applications

SUB-CATEGORY		DESCRIPTION
ENERGY SHIFTING	Short duration	Mostly involves using utility-scale energy storage to perform arbitrage and provide reliable capacity to meet peak system demand.
	Long duration	Long duration is intended to capture energy storage designed to deliver six hours or longer of stored energy (excluding pumped hydro), separating it from short duration. This category is technology-agnostic and may include lithium-ion battery energy storage, depending on market definitions.
ANCILLARY SERVICES		Using energy storage to provide operating reserves (such as frequency regulation, fast response, contingency reserves and others) through absorption or injection of short bursts of power. This is often procured by the system operator in the form of frequency regulation or reserves.
GRID REPLACEMENT	Transmission, Distribution	Energy storage can be installed at specific locations on the grid to better utilize existing transmission and distribution assets or defer reinforcement investment. For instance, storage assets can be located at grid congestion points and perform “virtual power lines”. They can also be used to provide an instantaneous response during peaking hours when an existing substation is overloaded.
CUSTOMER-SITED	Residential, Commercial and industrial (C&I)	Integrated at household (low voltage) and at commercial or industrial facilities (low/medium voltage). They can offer peak shaving (reducing peak demand in kW) and time-of-use optimization (shifting consumption of kWh from expensive peak time to less-expensive off-peak time). When combined with solar, can be used to increase the rate of self-consumption and serve as backup energy. Solar-plus-storage can be considered for both residential and C&I segments. Standalone batteries can also be considered in the C&I segment.
OTHER		Includes applications not covered in the major applications listed above, such as microgrids, virtual power plants (VPPs), EV charging and technology testing projects. This also includes projects without an announced application type in this category.
BUFFER		Capacity is an estimate/headroom not explicitly allocated to any specific application.

Future outlook and recommendations

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The global energy storage market is poised for substantial growth through to 2035, driven by falling battery costs, supportive policy frameworks, and the urgent need to integrate increasing renewable energy capacity. Despite near-term policy uncertainties — particularly U.S. tariff changes and China's shift from mandates to market-driven models — the sector is showing resilience, with annual additions expected to reach 92GW/247GWh in 2025, representing 23% year-on-year growth. While near-term expansion is being driven by the U.S. and China, emerging markets in Saudi Arabia, Sub-Saharan Africa, and Southeast Asia are accelerating deployment.

Lithium iron phosphate batteries are expected to dominate over the next decade, due to their cost-effectiveness, safety benefits, and a longer life cycle. Long-duration energy storage (6+ hours) should gradually increase to 4-6% of total capacity by 2028-2035, particularly in markets like the UK, U.S., Australia, Canada, Japan and South Korea. Utility-scale projects will dominate the market, representing 84% of annual gigawatt-hour build in 2025 and increasing thereafter. Behind-the-meter residential deployment will decline from 9% to 3% of total installations by 2035, as large-scale projects with extended duration take precedence.

Investment opportunities are evolving. The U.S. presents strong growth (235GW/948GWh by 2035) despite policy headwinds, supported by expanding domestic manufacturing and long-term tax credit availability through to 2033. Meanwhile, there are emerging high-growth markets in the EU, such as Italy (50GWh+ MACSE auction program.

Recommendations for application and duration

- Prioritize **utility-scale energy shifting projects** with 2 – 4 hour durations for near-term deployment, particularly co-located with solar assets in high-penetration markets
- Position for **long-duration opportunities** (6 – 12 hours) in markets with established procurement frameworks: UK cap-and-floor scheme (28.7GW pipeline), U.S. state-level (New York, Massachusetts targeting multi-GW), and Australia's revenue-underwriting agreements
- Consider **grid services and capacity market** participation in mature markets (UK, Poland, PJM) where long-term revenue contracts provide downside protection

Recommendations for supply chains and policy navigation

- Establish relationships with **battery manufacturers** expanding in the U.S. and consider Southeast Asian manufacturing partnerships to mitigate FEOC restrictions
- Monitor **emerging business models** including tolling agreements, floor-plus-revenue share deals, and two-way contracts for difference that are proliferating across European and Australian markets
- Track **auction program calendars** in Italy, Brazil, Argentina, Japan, South Korea, and various European markets where contracted revenues de-risk projects

Conclusion

The BESS market presents compelling investment opportunities through to 2035, with the sector transitioning from policy-dependent to increasingly economic-driven growth. Strategic investors should balance exposure across established markets offering contracted revenue certainty with selective positioning in high-growth emerging markets. The extension of battery durations, maturation of supply chains outside China, and proliferation of innovative commercial structures create multiple pathways for value creation. The success of any project will involve the active monitoring of evolving policy frameworks, particularly around domestic content requirements and trade restrictions, while maintaining flexibility in order to capture opportunities in markets where falling battery costs unlock new applications.

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Get in touch

General enquiries:

cleanenergyinfra@nuveenglobal.com

Joost Bergsma

Global Head of Clean Energy,
Nuveen Infrastructure
joost.bergsma@nuveenglobal.com

Francesco Cacciabue, CFA®

Global Head of Clean Energy Investments,
Nuveen Infrastructure
francesco.cacciabue@nuveenglobal.com

For more information about our clean energy infrastructure strategy please visit nuveen.com/cleanenergy.

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