On behalf of:

Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety

of the Federal Republic of Germany

IKI INTERNATIONAL CLIMATE INITIATIVE

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नवीन एवं नवीकरणीय ऊर्जा मंत्रालय
MINISTRY OF NEW AND RENEWABLE ENERGY
सत्यमेव जयते

GLOBAL INSIGHTS ON ENERGY STORAGE POLICIES:
Best Practices and Lessons Learned

Fraunhofer IEE

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This report has been prepared under the StoREin (Energy Storage for Renewable Energy Integration in India) project commissioned by the **German Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (BMUKN)** under the umbrella of the International Climate Initiative (IKI) and implemented by **Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH** in cooperation with the **Ministry of New and Renewable Energy (MNRE), Government of India.**

The report titled "***Global Insights on Energy Storage Policies: Best Practices and Lessons Learned"*** is an outcome of the analysis done under the policy and regulatory study. The report captures the best global practices in energy storage policy measures, as well as key takeaways for developing a flexible policy framework that promotes higher adoption of energy storage in a renewable-powered grid.

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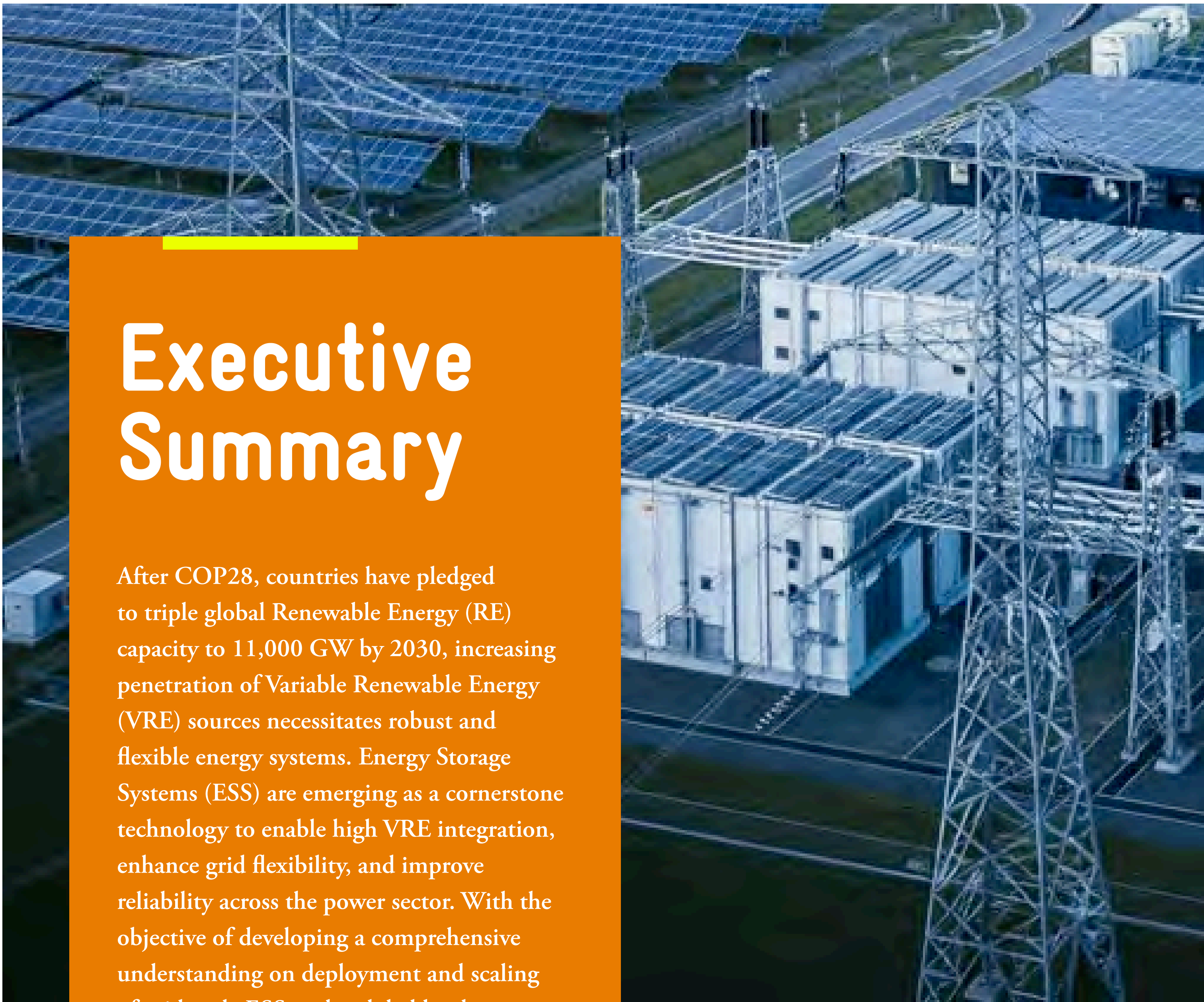
Abbreviations

AFRR	Automatic Frequency Restoration Reserve
BESS	Battery Energy Storage System
BTM	Behind-the-Meter
CAES	Compressed Air Energy Storage
CfD	Contract for Difference
CM	Capacity Market
COP28	28th Conference of the Parties
DER	Distributed Energy Resources
DISCOM	Distribution Company
DNO	Distribution Network Operator
DSO	Distribution System Operators
DUoS	Distribution Use of System
EMD	Electricity Market Design
EPR	Extended Producer Responsibility
ESS	Energy Storage System
EV	Electric Vehicle
EU	European Union
FCAS	Frequency Control Ancillary Services
FCR	Frequency Containment Reserve
FFR	Fast Frequency Response
GW	Gigawatt
GWh	Gigawatt-Hour
IPP	Independent Power Producer
ISO	Independent System Operator
ITC	Investment Tax Credit
LDES	Long Duration Energy Storage
mFRR	Manual Frequency Restoration Reserve
MW	Megawatt
MWh	Megawatt-hour
NDCs	Nationally Determined Contributions
PPP	Public-Private Partnerships
PHS/PSP	Pumped Hydro Storage / Plant
PV	Photovoltaic
RAB	Regulated Asset Base
RE	Renewable Energy
ToD	Time of Day Tariff
TSO	Transmission System Operator
VGF	Viability Gap Funding
VPP	Virtual Power Plant
VRE	Variable Renewable Energy



Executive Summary

After COP28, countries have pledged to triple global Renewable Energy (RE) capacity to 11,000 GW by 2030, increasing penetration of Variable Renewable Energy (VRE) sources necessitates robust and flexible energy systems. Energy Storage Systems (ESS) are emerging as a cornerstone technology to enable high VRE integration, enhance grid flexibility, and improve reliability across the power sector. With the objective of developing a comprehensive understanding on deployment and scaling of grid-scale ESS at the global level, a comparative literature review has been undertaken focusing on Germany, the United States (US), Australia, the United Kingdom (UK), Canada, and the European Union (EU) - all recognized as leading economies and frontrunners in shaping ESS deployment. This report highlights the enabling policy and regulatory frameworks, market design features, revenue generation opportunities, and business models that have improved the bankability and system value of ESS, offering actionable insights for countries aiming to build a flexible grid and promote ESS adoption:

Energy Storage Systems (ESS) are emerging as a cornerstone technology to enable high VRE integration, enhance grid flexibility, and improve reliability across the power sector.

A. Policy and Regulatory Frameworks

- *Progressive policy evolution and long-term strategic planning* are essential, moving from foundational legal recognition to comprehensive national strategies with clear targets. These frameworks provide stable investment signals and foster an enabling environment for ESS development. (Examples: Germany – EEG, NABEG; US – Energy Storage Grand Challenge; Australia – National Battery Strategy; UK – RE Roadmap; Canada – Ontario's DER Roadmap and Alberta's Energy Storage Roadmap; EU – Clean Energy Package)

- *Formal classification and legal recognition of ESS within energy legislation* are critical for removing regulatory ambiguities and resolving issues such as "double charging" on electricity duties or consumption levies. (Examples: Germany – Electricity Duty Act; UK – Energy Act 2023; EU – Clean Energy Package)

- *Targeted financial incentives and innovation support* reduce investment risk and promote technological progress. Mechanisms include capital subsidies, refundable tax credits, concessional financing, and competitive grants for advanced and long-duration technologies. (Examples: Germany – KfW 275, RES Act innovation auctions; US – Inflation Reduction Act ITC, DOE programs; Australia – CEFC, ARENA; Canada – SREPs, 30% refundable Clean Technology Investment Tax Credit; EU – Innovation Fund, Recovery and Resilience Facility (RRF), Italy's Superbonus, France's NEBEF)

- *Streamlined grid connection and interoperability guidelines* are essential for accelerating ESS deployment. Standardized technical rules and simplified connection procedures enable faster and more predictable project development. (Examples: Australia – AEMO Guidelines; Germany – KraftNAV Ordinance; UK – streamlined licensing process, Canada – Ontario Interoperability; EU – network codes under 2019 EU Electricity Regulation.).

- *Mandates for wholesale market integration and aggregation of Distributed Energy Resources (DERs)* are pivotal in enabling new business models such as Virtual Power

Plants and advancing a decentralized, flexible grid ecosystem. (Examples: US – FERC Orders No. 841 & 2222; UK – flexibility platforms; Canada – Ontario's DER Roadmap; EU – Electricity Directive 2019 allow aggregator-enabled BTM systems to access wholesale markets)

- *Environmental compliance and circular economy principles* are increasingly embedded through policies targeting battery lifecycle management, including Extended Producer Responsibility (EPR) for collection, recycling, and safe disposal. (Examples: EU Batteries Regulation, Germany – Battery Act; US – Battery and Critical Mineral Recycling Act)

B Market Structure and Grid Operation

- All frontrunner countries operate under *liberalized, unbundled electricity markets* that separate generation, transmission, distribution, and retail activities. This structure enables competitive ESS participation alongside traditional flexibility providers. (Examples: Germany, US, Australia, UK, Canada, EU – with the UK offering a fully liberalized market)
- *Decentralized regulatory authority, complemented by centralized market coordination* through entities such as RTOs/ISOs, allows region-specific market design while ensuring efficient service procurement and market functioning. (Examples: US – FERC, RTOs/ISOs; Canada – provincial autonomy with federal incentives; EU – national regulators with cross-border harmonization)
- *Multi-product market participation* allows ESS to access diverse revenue streams across day-ahead, real-time energy markets, capacity mechanisms, and ancillary services, optimizing value realization. (Examples: Germany – redispatch, ancillary services; US – energy, capacity, ancillary services; Australia – FCAS, FFR; UK – Capacity Market, frequency response; Canada – Ontario Market Renewal Programme enables multi-service participation; EU – balancing markets, PICASSO/MARI platforms)
- *Performance-based market participation* and transparency are maintained through mandatory performance standards, rigorous testing protocols, and data disclosure requirements, ensuring reliable ESS service delivery. (Examples: Germany – BNetzA standards; Australia – AEMO performance standards; UK – transparent compensation structures; Canada – IESO procurements; EU – enhanced access and aggregator rules)
- *Clearly defined roles for TSOs and DSOs* ensure they do not directly own ESS assets. Instead, they competitively procure location-specific flexibility to manage congestion and defer infrastructure upgrades. (Examples: UK – DNOs procure flexibility; Canada – DSOs in Ontario and Alberta; EU – storage classified as a market-based asset)
- Market mechanisms for grid congestion management mandate the use of flexible resources such as ESS to address overloads, strengthening the role of storage in system operations. (Examples: Germany – Redispatch 2.0; Australia – ISP forecasts for dispatchable resources; Canada – SREPs for Indigenous and remote applications)

C. Compensation Mechanisms and Business Models

- *Diverse revenue streams for value stacking are integral to ESS business models,* enabling participation across various market segments including energy arbitrage, ancillary services, and capacity markets. (Examples: Germany – merchant, utility-owned, hybrid RE+ESS; US – merchant, utility-owned, Virtual Power Plants; Australia – FCAS, arbitrage, FFR; UK – wholesale arbitrage, local flexibility; Canada – capacity contracts, merchant storage, BTM optimization via Ontario's DER Roadmap; EU – revenue stacking and cross-border trading)
- *Reliability-based payments and obligations* ensure system adequacy by incentivizing firm capacity, including ESS, particularly during peak demand conditions. (Examples: Australia – Retailer Reliability Obligation; UK – Capacity Market; Italy's capacity remuneration mechanism, Poland's capacity market, France's capacity mechanism; Canada – IESO's long term capacity payments)
- *Long-term revenue certainty mechanisms for* LDES provide financial stability by addressing higher upfront costs and longer payback periods, using tools such as minimum price guarantees and Cap-and-Floor

regimes. (Examples: UK – Cap-and-Floor for LDES; Australia – ISP forecasts and long-term agreements; EU – Italy's capacity remuneration mechanism, Greece's investment aid for LDES via RRF; Canada – SREPs, 30% refundable Clean Tech ITC)

- ESS is compensated for delivering *rapid grid stability services through market mechanisms* that reward fast frequency response, dynamic containment, and real-time flexibility. (Examples: Australia – FFR; UK – EFR, Dynamic Containment; Germany – FCR, aFRR, mFRR; EU – France's aFRR/mFRR markets, EU-wide cross-border aFRR/FCR platforms)

- *Payments for network support and demand-side flexibility* allow ESS operators to reduce infrastructure costs by managing congestion and contributing to wholesale market responsiveness during stress events. (Examples: Australia – Wholesale Demand Response; UK – DNO flexibility procurement; Canada – BTM systems participating via DER Roadmap)

- *Avoided charges and tax exemptions* improve project economics by addressing double-charging and grid usage penalties on stored electricity reinjected into the grid. (Examples: Germany – Electricity Duty Act exemptions; UK – removal of double-charging; Canada – BTM storage used to manage Global Adjustment and VPP participation)

- *ESS business models* have evolved across diverse deployment structures – including merchant storage by independent developers, utility-owned frameworks under RAB mechanisms, aggregator-led VPPs, hybrid RE+ESS projects. (Examples: ESS co-owned by indigenous communities in Canada, and value stacking with optimization services – to maximize revenue streams, enhance dispatchability, and support localized grid needs through non-ownership-based engagement by TSOs/DSOs).

Building on global best practices, India's evolving ESS landscape has also been offering adequate opportunities and challenges. However, significant policy and regulatory improvements are still required for acceleration of ESS deployment, especially at Distribution level. Key areas requiring greater attention include:

- Achieving central and state-wide policy alignment, particularly at the distribution level clarifying ownership and operation models and integrating storage into distribution and resource adequacy frameworks.

- Implementing Time-of-Day (ToD) tariffs with sufficient peak-non-peak price gaps to ensure viability of both grid-scale and BTM ESS business models.

- Early introduction of Capacity Market, which is essential for Discoms to manage Resource Adequacy,

- Institutionalizing DSOs and formally recognizing third-party aggregators at the state level, through licensing and registration schemes, which will revolutionize distribution operations.

- India's electricity market must also transition from shallow to deep, to enable diverse revenue streams for ESS, fostering competitive, transparent, and dynamic trading.

Aligning with global best practices – liberalized markets, structured ancillary services, and VPP-based aggregation – is crucial for unlocking ESS's full value, ensuring technical efficacy, institutional viability, and economic scalability.

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Background

Following the COP28 climate summit, 194 countries collectively pledged to triple global Renewable Energy (RE) capacity to at least 11,000 GW by 2030. Though, the combined RE capacity targets outlined in current Nationally Determined Contributions (NDCs) amount to just over 1,300 GW - only about 12% of the tripling goal (IEA, 2024). This emphasizes a critical need for all participating countries to reassess their RE ambitions and update their NDCs with a clear commitment toward achieving the global target.

Policy and regulatory frameworks play a pivotal role in developing an ecosystem that supports RE adoption, grid integration, and energy storage deployment. Based on IEA analysis of existing policies, plans, and estimates from nearly 150 countries, global RE capacity is projected to approach 8,000 GW by 2030. Current policies and plans in advanced economies project a near doubling of RE capacity by 2030, representing approximately 40% of the global target.

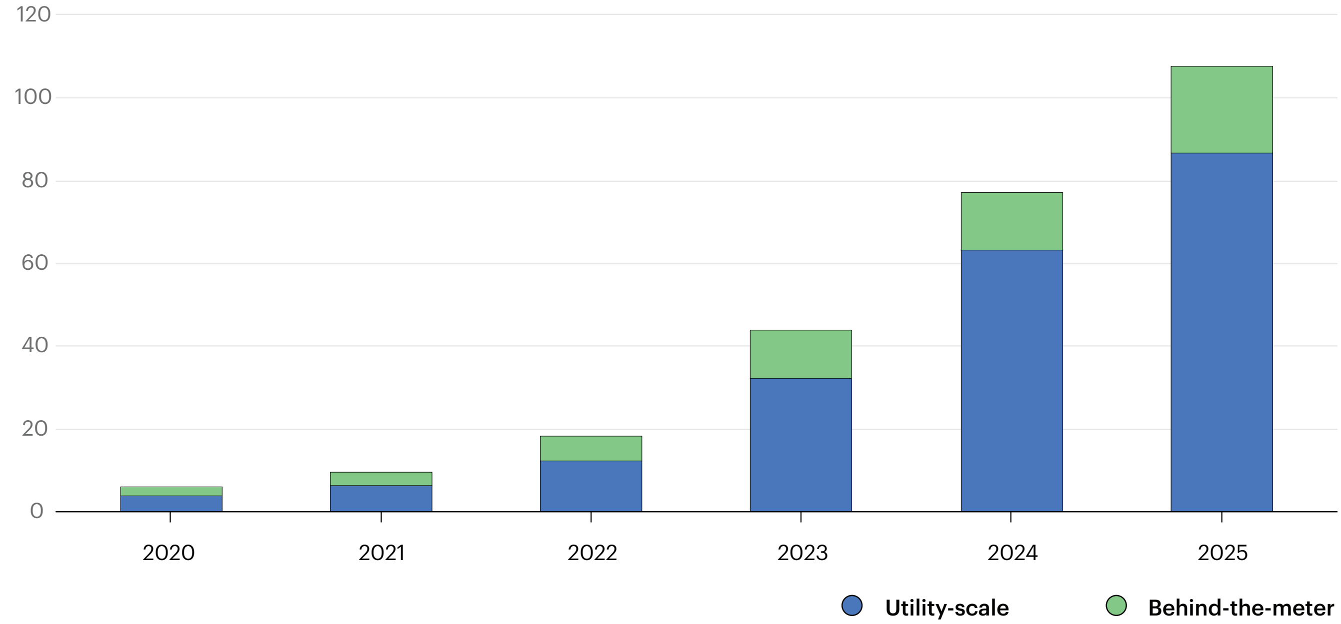
However, achieving these projections, particularly with the current composition of RE development, presents specific challenges. Countries primarily prioritize solar PV and wind energy in their ambitions, often overlooking hydropower, bioenergy, and other renewables. Variable renewable energy (VRE) makes up most countries' capacity, with solar PV at 50% and wind at 26%. High shares of VRE can pose operational challenges, particularly in terms of short-term flexibility and maintaining power system stability on sub-second timescales. One of the reasons for reduced power system stability is lack of inertia provision post contingency events from VRE. Unlike traditional synchronous generators, VRE sources are not electromagnetically coupled with the grid (IEA, 2025).

Effective integration of solar PV plants and wind turbine generators aids in stable power system operation. While power systems have always managed demand variability, VRE introduces supply variability depending on the weather. This variability will require increasing the flexibility of the entire power system, by leveraging dispatchable generation, grid enhancements, increased grid-connected energy storage and demand response (IEA, 2024).

Grid-scale energy storage plays a critical role in delivering essential grid supportive services such as short-term balancing, operating reserves, and ancillary support for grid stability. Additionally, it can defer the need for new investments in transmission and distribution infrastructure when it is co-located with Solar / Wind Plant. Importantly, it enables long-duration energy storage and supports grid restoration following blackouts (IEA, 2025).

Pumped-storage hydropower remains the most widely preferred energy storage technology and still holds considerable untapped potential in several regions. Batteries, on the other hand, are the most scalable form of grid-scale storage and have experienced rapid market growth in recent years in view of faster project execution / installation. The global gross battery storage capacity addition per year and the electricity storage project cost per kWh are presented in the image below:

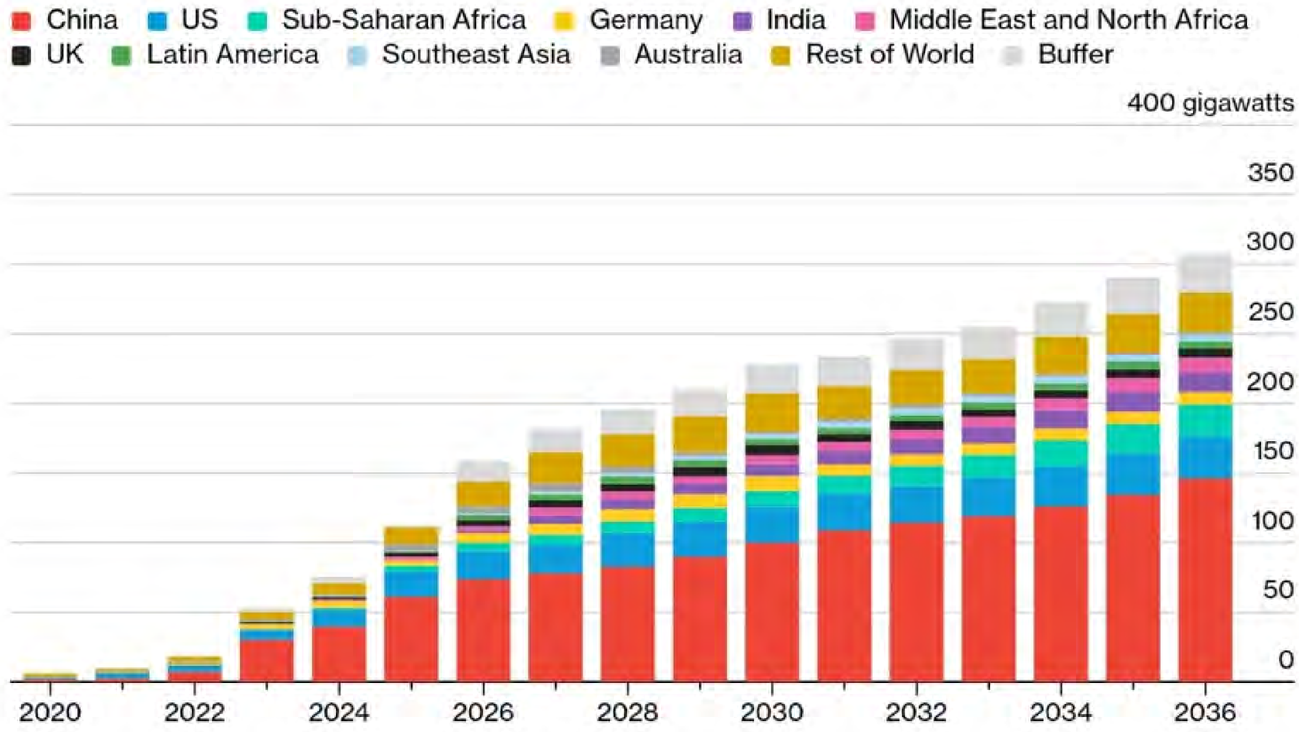
Figure 1: Global Battery Storage Capacity Addition: 2020-2025



Source: (IEA, 2026)

The energy storage project development is increasingly driven by the utility-scale segment, with mandates and targeted auctions promoting gigawatt-hour scale projects in global markets. As of 7 May 2026, BloombergNEF estimates energy storage additions to increase by 48% this year, setting a record for annual additions at 112 GW (307 GWh), excluding PSP projects. Within this new capacity, Lithium iron phosphate remains the prevalent lithium-ion battery chemistry in the stationary energy storage market. This significant year will be succeeded by a higher compound annual growth rate through to 2036, with annual additions are expected to reach 308 GW by that year, as shown below:

Figure 2: Global Gross Energy Storage Additions by Market till 2036



Source: (BloombergNEF, 2026)

This anticipated growth is driven by continued advancements in battery technologies, declining system costs, enhanced grid integration needs, and supportive policy and regulatory frameworks across key markets. Meeting the growing demand for system flexibility while simultaneously advancing deep decarbonisation of electricity generation remains a critical challenge for the global power sector.

Addressing this issue requires the mobilisation of all available flexibility resources, including grid-scale energy storage systems ESS. However, in liberalised electricity markets, the deployment of large-scale storage has been impeded by structural barriers such as long permitting processes, extended lead times, and a lack of long-term revenue certainty (IEA, 2025). These challenges collectively repeal investor confidence and delay market uptake.

In order to remove these roadblocks, the policy and regulatory frameworks that make sure level play among different flexibility solutions are needed to be updated on a regular basis. A well-designed, technology-neutral regulatory environment is essential for unlocking the full economic potential of energy storage by recognising and adequately compensating its diverse value streams. This, in turn, can significantly accelerate the integration of ESS into modern power systems.

The following chapter presents a deep dive analysis of selected advanced economies to explore the policy and regulatory instruments that have acted as key enablers for the promotion and deployment of energy storage. By identifying best practices, supportive market structures, and enabling regulatory frameworks, the analysis aims to generate actionable insights for emerging economies seeking to build resilient and sustainable energy storage ecosystems.

02

Policy and Regulatory enablers for ESS:
Learnings from Global Best Practices

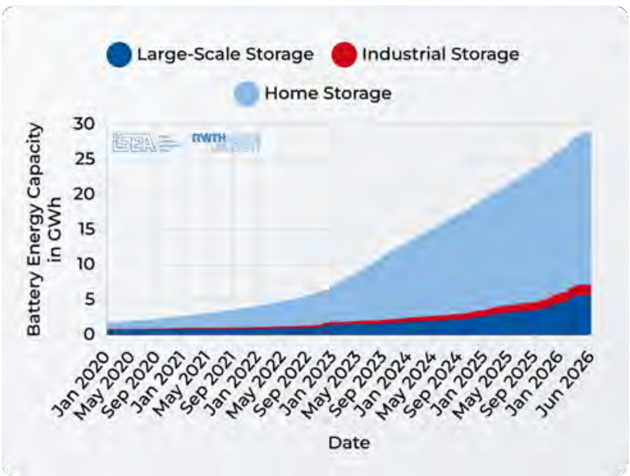
Findings from the detailed study on Germany, the United States (US), Australia, the United Kingdom (UK), Canada, and the European Union (EU) are presented below:

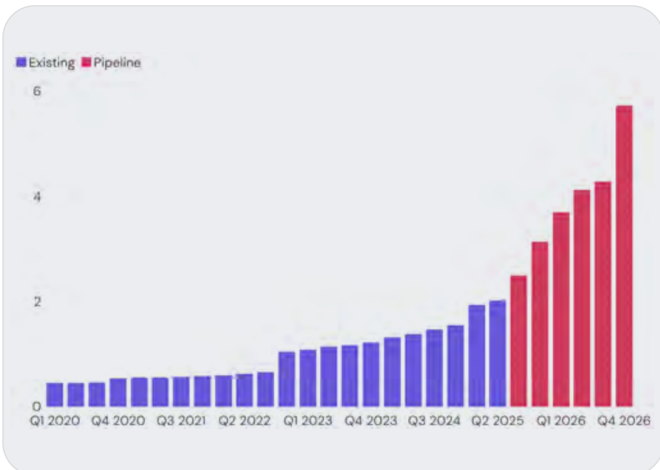
GERMANY

Germany has set an ambitious aim of becoming greenhouse gas neutral by 2045. As its power system shifts toward greater dependence on variable renewable generation, Germany aims to generate 600 TWh of electricity, or 80% of total consumption, from RE sources by 2030, emphasizing a significant market ramp-up of ESS (BMWK, 2023). Currently, Germany has 17.37 GWh of installed and operational residential storage battery capacity, 0.45 GWh of industrial storage battery capacity, and 2.96 GWh of large-scale storage battery capacity, with numerous additional projects under construction (Battery Charts, 2026).

Nonetheless, Germany recognises the need for even higher volumes of ESS deployment - particularly at utility scale - to ensure robust security of supply throughout its electricity transition. With 473 MW of additional battery capacity coming online in 2025, Germany's operational battery power is set to reach 2.1 GW by Q2 2025. At present, grid-scale batteries in Germany have an average duration of 1.4 hours.

Figure 3: Germany's ESS Market





Source: Battery-Charts (2026) and Modo Energy (2026)

Policy and regulatory frameworks

Germany has progressively developed a robust policies and regulations to support the deployment and integration of ESS, mentioned in a timeline manner (BMWK, 2022):

- 2015 - Renewable Energy Sources Act (EEG): This change to the EEG formalized incentives for the development of battery energy storage systems (BESS) in conjunction with solar photovoltaic (PV) installations. It was the first legislation to acknowledge ESS as a critical enabler of renewable energy integration, particularly in decentralized energy generation (BMWK, 2017).
- 2016 - Electricity Market Act: The Electricity Market Act laid the foundation for a liberalised yet secure energy market. It authorized transmission system operators (TSOs) to manage ancillary services, particularly grid frequency balancing. It delineated the operational timelines for various balancing reserves (Interreg, 2016):
  - Frequency Containment Reserve (FCR): within 30 seconds
  - Automatic Frequency Restoration Reserve (aFRR): within 5 minutes
  - Manual Frequency Restoration Reserve (mFRR): within 15 minutes
- 2016 - KfW 275 Program: Launched by the state-owned development bank KfW, this program provided up to 30% capital subsidies for residential solar-plus-storage installations. The program aimed to deploy 50,000 such systems by 2020 and facilitated significant growth in behind-the-meter ESS applications (Enkhardt, 2017).
- 2018 - Federal Network Agency (BNetzA): The BNetzA regulates grid connection procedures through the Power Plant Grid Connection Ordinance (KraftNAV) and implements the European Electricity Balancing Guideline (EBGL). These regulations provide clarity on the technical and operational criteria for connecting ESS to the grid.
- 2021 - Grid Expansion Acceleration Act (NABEG): This act introduced Redispatch 2.0, a framework that mandates the use of flexible resources, including ESS, to alleviate grid congestion and prevent network overloads. This policy shift strengthened the role of storage as a non-generation asset in system operations (Vattenfall, 2021).
- 2021 - German Battery Act (BattG): Transposing the EU Battery Directive, this act mandates Extended Producer Responsibility (EPR) for batteries, ensuring environmental compliance across the ESS supply chain (BMUKN, 2021).
- 2022 - Energy Industry Act (EnWG): Amendments to the EnWG formally classified large-scale ESS as controllable consumption equipment. This classification enabled grid feed-in exemptions for storage facilities, thereby improving their operational economics (BMWK, 2023).
- 2023 - Electricity Duty Act: This act exempted stationary battery storage and pumped storage hydropower (PSP) facilities from electricity duties when the stored electricity is reinjected into the grid. This significantly improved the financial viability of grid-scale storage systems (BMWK, 2023).
- 2023 - Energy Financing Act: This law introduced targeted incentives to promote market-based participation and bidirectional functionality of ESS assets. It promotes ESS as both consumers and providers of electricity (BMWK, 2023).
- 2023 - Renewable Energy Sources Act (RES Act): Innovation auctions were introduced under this act to incentivize hybrid systems, particularly combining renewable energy installations with BESS units. These auctions aim to stimulate innovative deployment and operational strategies (BMWK, 2023).
- 2023 - Exemption from Financial Contributions to Grid Construction Costs (BKZ): Small-scale storage systems (up to 30 kW) connected to the Low Voltage grid are exempted from financial contributions toward grid infrastructure development. This policy directly benefits residential and community-scale ESS deployment (BMWK, 2023).

German regulatory framework for electricity storage is undergoing a significant overhaul in 2025–2026 to enhance flexibility, grid integration, and market participation. Some of the key changes include:

- Amendments to the EEG (§ 19 3a–3c) and EnWG (§ 14a EnWG) ("Solar Peak / Solar Flexibility Package", 2025): Electricity storage systems may charge from the public grid without automatically losing eligibility for EEG support, provided that charging and discharging volumes are properly metered and allocated. In parallel, the regulatory framework strengthens controllability and system-oriented operation of storage via smart metering and flexibility rules.

- EEG Amendment 2025 (§ 19 3a–3c, §§ 21, 24) – New funding options for storage systems: The EEG introduces additional funding mechanisms (e.g. deferral and flat-rate options) that allow storage systems to remain eligible for support even if they are not charged exclusively with renewable electricity. This explicitly recognises storage as a flexibility instrument rather than a purely renewable-only asset.
- EnWG amendment and building law reform – privileging of large storage facilities (2025) (§ 35 1 nos. 10–11 BauGB, §§ 11a, 12 EnWG): Large battery storage facilities are granted privileged status under planning law, significantly simplifying approval procedures, particularly in outdoor areas. At the same time, energy law clarifies the role of storage as an independent system asset to be considered in grid planning and operation.
- Federal Network Agency implementation rules (MiSpeL framework, from 2025 onward, § 19 EEG, §§ 21b, 24 EnWG): The Federal Network Agency specifies binding rules for metering, allocation and, where applicable, generalize of electricity volumes in storage systems, enabling lawful separation of EEG-eligible and non-eligible energy. These rules operationalise the new EEG funding options for storage in practice.

Market structure and grid operation

Germany's power market is governed by the Federal Network Agency (BNetzA), and it is aligned with EU directives for market liberalization and system flexibility. Germany operates under a liberalised electricity market framework, with multiple stakeholders including TSOs, DSOs, aggregators, and balancing service providers, where economic dispatch is determined by market participants through bids and offers (through trading platform, e.g. EPEX Spot). The physical operation and security of the grid are managed by four main TSOs:

a. 50Hertz (northeast Germany)

b. TenneT (central Germany)

c. Amprion (west Germany)

d. TransnetBW (southwest Germany)

Each TSO operates its respective control area, responsible for procuring essential ancillary services like frequency

Figure 4: Germany's power market operation

Source: (SMARD, 2025)

containment, frequency restoration, and reserve capacity through competitive markets. This procurement ensures grid stability, though TSOs may also intervene post-market clearing, via Redispatch or balancing reserves, to resolve physical constraints or uphold grid security.

ESS participate in these markets either directly or via aggregators. Participation is regulated by the BNetzA, which mandates performance standards, testing protocols, and data transparency requirements. BESS assets are increasingly being integrated into balancing markets due to their rapid response capabilities and modular scalability.

Compensation mechanisms and business models

Germany offers a combination of regulated and market-based compensation mechanisms for ESS. Revenue streams include (Bundesnetzagentur , 2025):

- Frequency Containment Reserve (FCR) Payments: ESS providing FCR receive capacity payments through weekly auctions administered by TSOs.
- Energy Arbitrage: BESS units buy electricity at low wholesale market prices and sell during peak hours.
- Avoided Grid Fees and Electricity Duty Exemptions: Large-scale ESS are exempt from certain grid usage charges under the EnWG and as per the 2023 Electricity Duty Act, ESS are exempt from electricity duties when energy is discharged into the grid.

- Innovation Auctions: Under the RES Act, hybrid RE+ESS projects can compete for innovation premiums.
- Redispatch Payments: Storage systems providing redispatch services under NABEG 2.0 are compensated for capacity and operational availability.

Business Models:

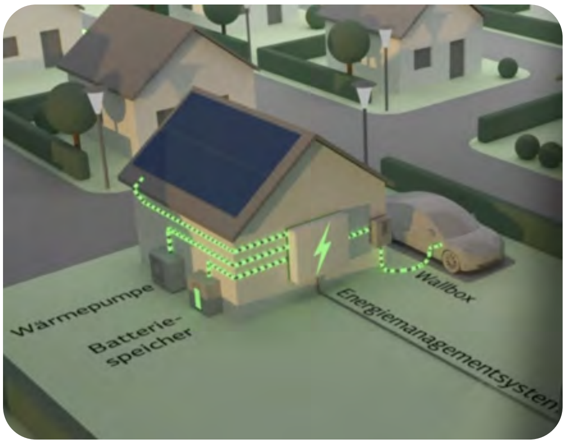
- Aggregator-based Participation: Smaller ESS units are pooled by aggregators to bid into balancing markets.
- Utility-owned Models: TSOs and DSOs deploy large storage assets for grid support under regulated asset base (RAB) frameworks.
- Merchant Storage: Independent power producers (IPPs) operate ESS based on arbitrage and ancillary service revenues.
- Hybrid RE-Storage Projects: Co-located systems participate in both feed-in tariff schemes and ancillary markets, optimising dispatch.

Germany's energy storage market has transitioned away from traditional FITs for renewables under the EEG Act towards competitive auctions and market-integration mechanisms. Energy storage is allowed to compete for capacity contracts on an equal basis with conventional generation and other technologies, signalling a clear shift toward market-based remuneration rather than fixed tariffs. In parallel, price volatility and flexible pricing in grid tariffs favour BESS that can arbitrage energy while providing peak-shaving and system support, thereby enhancing their commercial viability (Trina Solar, 2025).

Germany's regulatory clarity, combined with multiple access points to compensation mechanisms, creates a strong business case for ESS deployment.

KEY TAKEWAYS

- **Germany has progressively developed a robust policy landscape (e.g., EEG, Electricity Market Act) formally integrating ESS. This enables their participation in ancillary services (like frequency containment and restoration) and ensures transparent technical and operational criteria for grid connection.**
- **NABEG introduces "Redispatch 2.0," mandating ESS use as flexible resources to alleviate grid congestion. TSOs' procurement of balancing reserves through competitive markets further ensures physical grid security.**
- **Programs like KfW 275 offered capital subsidies for residential storage, while the Energy Industry Act (EnWG) and Electricity Duty Act provide significant financial viability through grid feed-in and duty exemptions for large-scale ESS.**
- **Innovation auctions incentivize hybrid RE+ESS projects, stimulating advanced deployment strategies. Additionally, the German Battery Act (BattG) mandates EPR, fostering environmental compliance and sustainability across the ESS supply chain.**



CASE STUDY

KFW PROGRAM 275

GERMANY

KfW Renewable Energies Programme 275 – Financing of stationary battery storage systems in conjunction with a solar PV system

One of the world's most successful policy-driven residential energy storage programmes, designed to accelerate PV-plus-battery adoption and support Germany's Energy Transition. The programme stimulates market growth and technological development of battery storage systems, while subsidized systems paired with rooftop solar PV enable better integration of small to medium-sized PV systems into the electricity grid.

CURRENT STATUS Active during 2013 to 2018

CONTEXT

- Germany's power system is characterized by high penetration of distributed solar PV and centralized wind power, leading to increasing challenges related to grid congestion, curtailment, and midday solar surplus.
- Rapid reductions in feed-in tariffs (FiTs) under the EEG Act resulted in FiTs falling below household retail electricity prices, making self-consumption more attractive than export.
- Residential electricity prices in Germany are among the highest in Europe, strengthening the economic rationale for behind-the-meter storage.
- To address these challenges and accelerate storage deployment, the German government introduced KfW Programme 275, combining investment grants and low-interest loans for residential battery systems paired with PV.
- The programme also aimed to ensure that batteries are operated in a grid-friendly manner, contributing to system stability rather than exacerbating peaks.

TOTAL COSTS

Typical residential battery system costs during early programme years: €800–1,200 per kWh - substantial cost reductions observed during the programme lifecycle,

Maximum subsidy limits up to €600 per kW of storage; Maximum repayment bonus €3,000 per system,

KfW loans covered up to 100% of eligible investment costs, reducing upfront financial barriers for households.

STAKEHOLDERS

BMWi/BMWK – policy design and subsidy funding,

KfW Bank – programme implementation and concessional financing, Residential PV system owners – primary beneficiaries, Others (Battery and inverter OEMs, DSOs, Aggregators and utilities) – technology supplier and flexibility service providers

FUNDING SOURCES

Federal Government of Germany (repayment subsidies), KfW Bank low-interest loans, Private household investment (remaining capital costs)

ACTIVITIES

- The KfW Programme 275 was implemented through a structured policy and financing framework:
- Introduced in 2013, the programme offered a repayment subsidy of up to 30% of eligible battery system costs, combined with low-interest loans from KfW Bank.
- Eligible systems included new PV-plus-battery installations as well as retrofit battery systems connected to existing PV plants.
- Programme eligibility conditions included: Maximum PV system size: 30 kWp, Minimum battery operation period: 5 years, Battery warranty requirement: 10 years (current value replacement guarantee), Maximum grid feed-in cap: PV export limited to 50–60% of nominal PV capacity, incentivizing self-consumption and peak shaving.
- Subsidy levels were progressively reduced over time (from ~30% to ~10% by 2018), reflecting falling battery costs and market maturation.
- Batteries were required to have remote control and communication interfaces, enabling future aggregation, virtual power plant (VPP) participation, and system operator access.
- The programme officially ended in 2018 after successfully stimulating a self-sustaining residential storage market. Residential batteries are increasingly aggregated by utilities and aggregators to provide balancing, reserve, and grid support services.

IMPACTS

AT LOCAL LEVEL

- Increased PV self-consumption in households, reducing grid exports during peak solar hours.
- Improved voltage stability and congestion management in low-voltage distribution networks.
- Reduced household electricity bills and improved energy autonomy.
- Deployment of grid-responsive battery systems with communication and control capabilities

AT COUNTRY LEVEL

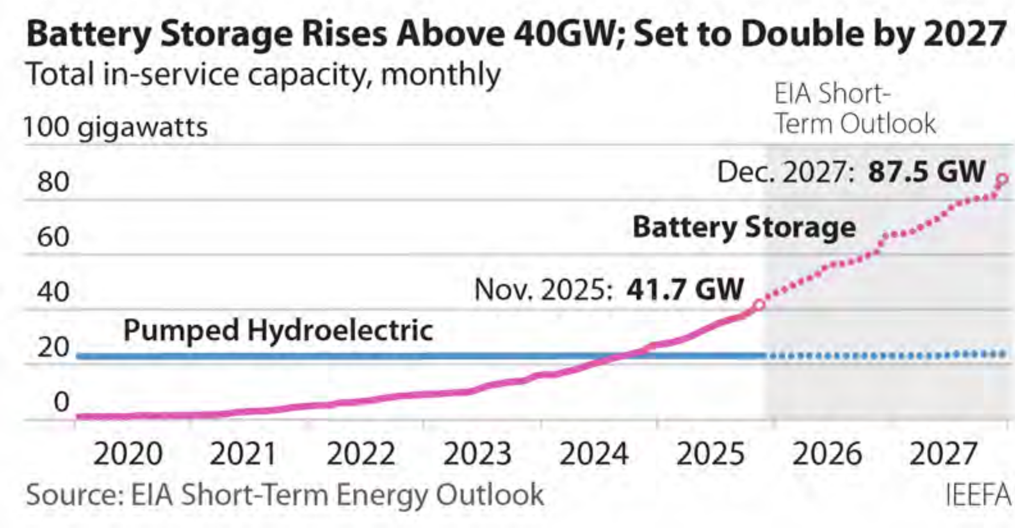
- Reduced PV curtailment and localized grid congestion
- Supported higher penetration of distributed renewables while maintaining system reliability.
- Created a foundation for aggregated residential storage to provide balancing and reserve services
- Supported Germany's broader energy transition objectives through distributed flexibility.

UNITED STATES

The US energy storage market is expanding rapidly, boosted by ambitious energy transition plans aimed at achieving 160 GW of standalone BESS capacity by 2050 (EIA, 2023). With a remarkable 10.4 GW installed during the year, utility-scale BESS topped 26 GW in total capacity in 2024, making it the second-largest producing capacity gain after solar. Even with this quick expansion, BESS only accounted for 2% of the 1,230 GW of utility-scale power generation capacity in the U.S. (EIA, 2025). The U.S. Energy Information Administration's (EIA) latest short-term outlook understates the amount of BESS capacity that will be installed by 2027, as shown in the Figure 5.

Alongside batteries, the country also utilizes PSP, with 40 plants operating across 18 states, providing 22 GW of nameplate power capacity (EIA, 2023). The U.S. has enabled an evolving power market through a combination of supportive federal policies and state-level mandates, which together create a conducive environment for large-scale deployment of advanced ESS systems.

Figure 5: U.S. ESS Market (2020-2027)



Source: U.S. EIA Short-term Outlook (2026)

Policy and regulatory frameworks

Over the last decade, the U.S. has made significant strides in establishing a robust policy and regulatory foundation to support the deployment and integration of grid-scale ESS (FERC, 2025):

- 2013 – FERC Order No. 784: Allows third-party suppliers to supply supplementary services such as frequency regulation, enhancing market competitiveness and operational flexibility. It made transmission companies pay for regulation services based on speed and accuracy, which paved the way for energy storage to show off its special qualities (FERC, 2013).
- 2013 – Hydropower Regulatory Efficiency Act: This streamlined the licensing process for smaller hydropower projects, including pumped storage hydropower (PSH) facilities, particularly those located off-river or in closed-loop systems (U.S. Congress, 2013).
- 2018 – FERC Order No. 841: A landmark regulation directing regional transmission organizations (RTOs) and independent system operators (ISOs) to include electric storage resources (ESRs) into wholesale markets. It calls for market rules to allow storage to participate in the energy, capacity, and ancillary services markets on a level basis with other generation resources (FERC, 2018).
- 2020 – Energy Storage Grand Challenge (ESGC): The Department of Energy (DOE) initiated this cross-agency program, which aims to reduce long-duration energy storage (LDES) costs by 90% by 2030. It promotes fundamental research, technological development, and system integration to promote the United States as a global leader in ESS innovation (US DoE, 2020).

- 2020 – Battery and Critical Mineral Recycling Act: Established regulatory mechanisms for the collection, recycling, and safe disposal of lithium-ion and nickel-cadmium batteries used in grid-scale storage. This policy supports sustainability and circularity in ESS deployment (US Congress, 2021).
- 2021 – Infrastructure Investment and Jobs Act (IIJA): $1.2 trillion in federal infrastructure spending was approved, with $355 million set out especially for energy storage demonstration projects. It fosters innovation in storage applications such as microgrids, grid resilience, and renewable integration (GFoA, 2021).
- 2020 – FERC Order No. 2222: Allows for the aggregation of DERs, including behind-the-meter storage, to participate in wholesale markets. It promotes a decentralized, consumer-driven energy economy and opens up new business models like Virtual Power Plants (VPPs) (FERC Order No. 2222, 2020).
- 2022 – Inflation Reduction Act (IRA): Provided Investment Tax Credits (ITC) for standalone storage systems for the first time. This measure significantly lowers the financial barrier to deploying both co-located and independent ESS installations (US DoE, 2022).
- 2023 – Storage Innovations 2030: The DOE released a suite of strategic reports detailing R&D pathways to commercialize LDES technologies. These documents serve as roadmaps for scaling innovative storage applications and lowering system costs (US DoE, 2023).

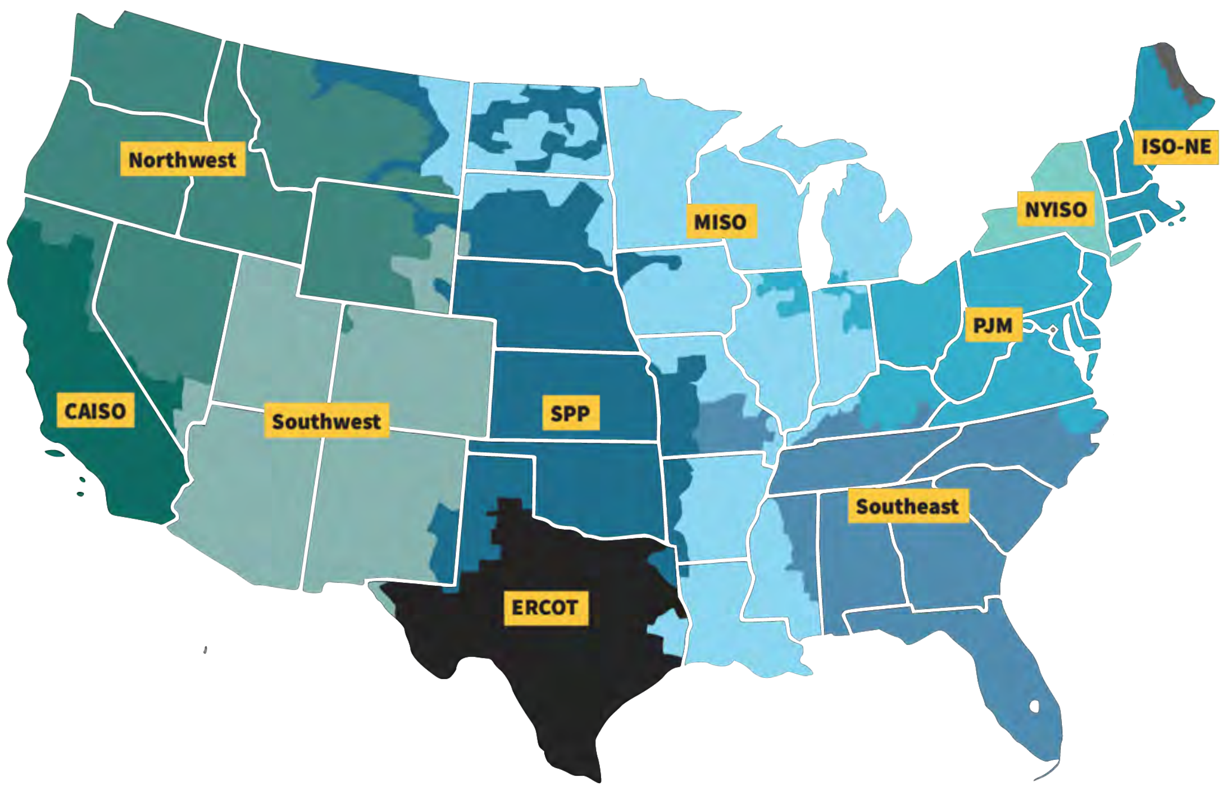
Market structure and grid operation

The U.S. has a decentralized regulatory framework. The Federal Energy Regulatory Commission (FERC) regulates interstate power markets, although individual states maintain control over distribution and retail operations (FERC Order No. 2222, 2020).

The U.S. has a hybrid energy market structure composed of regional wholesale markets managed by RTOs/ISOs and vertically integrated utility territories. In RTO/ISO markets like as PJM, CAISO, MISO, ERCOT, NYISO, and ISO-NE, ESS can actively engage in a variety of market products such as energy, capacity, and auxiliary services.

Traditional wholesale electricity markets are mainly located in the Southeast, Southwest, and Northwest. Utilities in these locations are responsible for system operations and management, as well as providing power to retail customers.

Figure 6: U.S. power market operation



Source: (FERC, 2025)

Compensation mechanisms and business models

ESS in the U.S. derive value through multiple revenue streams, both in regulated and deregulated markets. Compensation mechanisms have evolved to reflect the multi-service nature of storage technologies (CAISO, 2025):

- Day-Ahead Market & Real-Time Market: Energy storage systems can actively participate in both forward and real-time energy markets, achieving energy arbitrage by charging when prices are low and discharging when prices are high.
- Ancillary Services: Storage resources are crucial for providing essential grid stability services, including:
  - Frequency Regulation (Regulation Up and Down): Rapidly injecting or absorbing power to maintain grid frequency.
  - Operating Reserves (Spinning and Non-Spinning Reserve): Providing capacity that can be rapidly dispatched to handle unexpected supply-demand imbalances.
- Grid Stability and Reliability: The inherent flexibility and rapid response capabilities of energy storage position them as key assets for supporting critical grid functions and enhancing overall system reliability within the RTO/ISO operational framework.

Business models

- Merchant developers (e.g. LS Power and Fluence) deploy energy storage as independent projects.
- Utility-owned storage involves regulated utilities deploying storage as an integral part of their grid infrastructure.
- Aggregator models and VPPs allow DER aggregators such as Sunrun and Tesla to combine small systems into market-scale assets (FERC Order No. 2222, 2020).

The U.S. wholesale electricity markets have restructured tariff and participation rules to enable storage to compete in energy, capacity, and ancillary service markets. FERC Order No. 841 requires RTOs/ISOs to revise tariffs to allow electric storage resources (including BESS) to participate fairly in capacity, energy, and ancillary services markets, recognizing the unique characteristics of storage (FERC, 2018). The energy arbitrage remains a major revenue source for electric storage in the U.S (Marija Maisch, 2025).

The U.S. has established a comprehensive and progressive policy, regulatory, and market framework that positions ESS as a critical enabler for grid modernization, renewable integration, and enhanced energy resilience.

KEY TAKEWAYS

- **The hybrid U.S. market structure - combining RTO/ISO-operated wholesale markets with vertically integrated utilities, enables business models such as merchant storage, utility-owned systems, and aggregator-led VPPs, effectively unlocking value stacking opportunities for ESS.**
- **The evolving U.S. policy landscape addresses market access, technical integration, and fair compensation, enabling ESS to deliver vital grid services like frequency regulation and operating reserves.**
- **Strong federal support, including standalone storage Investment Tax Credits under the Inflation Reduction Act, reduces upfront costs, while programs like the Energy Storage Grand Challenge accelerate innovation in advanced and long-duration technologies.**
- **Strategic investment in the domestic battery supply chain - through the Battery and Critical Mineral Recycling Act and federally funded demonstration projects - drives sustainable ESS deployment and strengthens national grid resilience.**

CASE STUDY

PJM INTERCONNECTION –

Ancillary Services & Storage Market Design

UNITED STATES

Market-wide ancillary services framework enabling large-scale and distributed battery energy storage participation.

PJM Interconnection is the world's largest competitive wholesale electricity market and a global reference for market-based integration of BESS, particularly through frequency regulation market reforms that enabled fast-responding storage resources to compete with conventional generators.

CURRENT STATUS Operational since 2001

CONTEXT

- PJM Interconnection operates the wholesale electricity markets and transmission system across 13 U.S. states and Washington D.C., serving over 65 million consumers under Federal Energy Regulatory Commission (FERC) oversight.
- Under the Accelerated scenario, retirements of coal, natural gas and oil generators extend to 71 GW, requiring a 275 GW buildout of renewables and storage.
- Despite 275 GW of renewables and storage (including BESS of 27.47 GW), 79 GW of flexible thermal resources are still needed to maintain resource adequacy under the one-in-10 loss-of-load expectation - this poses a challenge as the energy transition progresses.
- At the same time, increasing penetration of renewable energy, retirement of conventional thermal plants, and growing system demand created a need for fast, accurate frequency control services beyond the capability of traditional generators.
- Prior to reform, frequency regulation markets compensated all resources uniformly, despite large differences in response speed and accuracy, which limited participation of advanced storage technologies.
- To address these challenges, PJM introduced power market reforms and established a technology-neutral, performance-based framework that strongly favored battery storage.

TOTAL COSTS

No direct capital subsidy from government and costs are recovered through market-based payments

STAKEHOLDERS

PJM Interconnection – Market Operator, FERC – Regulator, Public Utility Commissions - State Utility Regulators, Battery storage developers, operators, generators – Participants, End-user - Consumers

FUNDING SOURCES

Private investment driven by market signals and performance-based revenues.

ACTIVITIES

PJM implemented a structured reform of its Ancillary Services market, focusing on frequency regulation:

- **Ancillary Service Markets:** Ancillary services balance the transmission system from source to consumer through the Regulation Market (Real-Time only) and three reserve markets - Synchronized, Non-Synchronized, and Secondary - operating in both Day-Ahead and Real-Time.
- **Frequency Regulation Reform:** Under FERC Order 755, PJM introduced Pay-for-Performance by splitting regulation into RegA (slow, sustained response for traditional units) and RegD (fast, high-accuracy dynamic signal optimized for batteries).
- **Performance-Based Payments:** Regulation compensation is strictly calculated based on three factors: the capacity reserved (MW), the mileage (total movement), and a performance score that measures accuracy and speed.
- **Storage Integration Rules:** Batteries are enabled to participate across multiple markets as regulation and reserve resources, utilizing energy-neutral regulation signals to provide continuous grid services without exhausting their state-of-charge.
- PJM's storage participation aligns with broader market reforms, specifically FERC Order 841 for electric storage participation and FERC Order 2222 for evolving distributed energy resource (DER) aggregation.

IMPACTS

AT LOCAL LEVEL

- In the PJM Pepco zone covering Washington, DC, higher capacity clearing prices highlight the growing value of fast, accurate frequency regulation and reserve services, particularly from battery energy storage resources in PJM's ancillary services markets.
- From June 2025, the $10 increase in average residential monthly bills (9%) reflects system reliability costs under tightening supply and rising demand, reinforcing the role of performance-based ancillary services in maintaining grid stability.
- Commercial and residential customers face greater price volatility driven by reliability needs, underscoring the importance of efficient regulation and reserve markets that reward high-performing storage and demand-side resources.

AT COUNTRY LEVEL

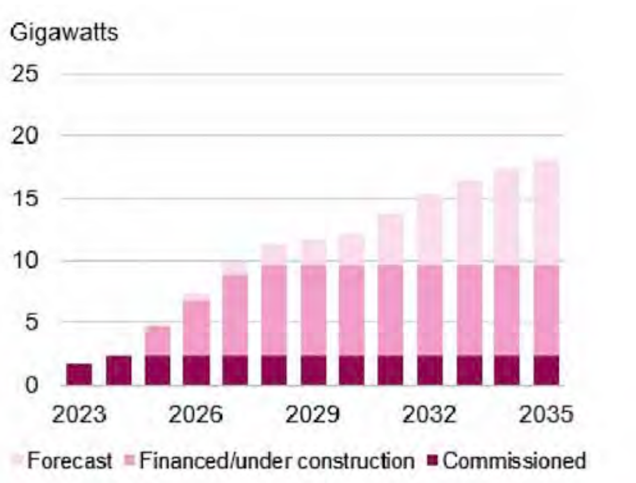
- PJM-wide capacity prices increased by a factor of nine, raising total capacity costs from $2.2 billion to $14.7 billion, signaling system-wide reliability stress and strengthening the case for market-wide ancillary services frameworks that value speed and accuracy.
- The price surge reflects declining existing supply, barriers to new entry, and rising demand, conditions under which ancillary services from storage and flexible resources are critical to balance the grid.
- FERC-approved reforms, along with interconnection queue reform and the Resource Reliability Initiative, reinforce technology-neutral market designs and aim to bring reliable and flexible resources online, supporting national reliability objectives and higher storage and advanced grid services participation.

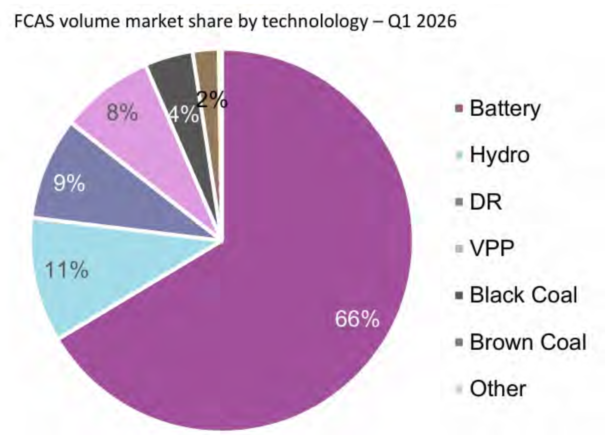
AUSTRALIA

In recent years, Australia has seen a considerable increase in utility-scale battery installations. This spike is directly related to several critical aspects, including sustained high price volatility in the electricity market, supporting government policies, and the projected closure of coal power units. According to the Australian Energy Market Operator (AEMO)'s Integrated System Plan (ISP) for 2020, 6 - 19 GW of new dispatchable resources (utility-scale PSP, large-scale BESS, distributed batteries, VPPs, and other demand-side involvement) are required by 2040 (AEMO, 2020).

The country's utility-scale battery capacity is predicted to increase eightfold, from 2.3 GW in 2024 to about 18 GW by 2035. Between Q1 2024 and Q1 2025, the average battery availability increased by 46%, from 819 MW to 1,193 MW (BNEF, 2025). Meanwhile, FCAS costs totalled $14 million, with batteries continuing the predominant source of FCAS provision in Q1 2026 (AEMO, 2026).

Figure 7: Australia's ESS Market





Policy and regulatory frameworks

Australia's regulatory landscape has evolved significantly over the past decade to facilitate the deployment of ESS, especially in the context of integrating renewable energy and providing system flexibility. Key policies and regulations include (AEMO, 2025):

- 2015 – Electricity Statement of Opportunities (ESOO): The Australian Energy Market Operator (AEMO) releases the ESOO annually, which gives a 10-year outlook on energy dependability across the National Electricity Market (NEM). It highlights the need for investments in generation, demand response, and storage technologies to ensure a stable electricity supply (AEMO, 2015).
- 2017 – AEMC's Frequency Control Ancillary Services (FCAS) Reform: The Australian Energy Market Commission (AEMC) enabled Market Ancillary Service Providers (MASPs) to classify loads, such as batteries, to deliver frequency response services. This reform expanded the scope of ESS participation in primary frequency control, encouraging a competitive market for ancillary services (AEMC, 2017).
- 2018 – National Electricity Rules (NER) Amendments: The NER were revised to streamline the grid connection process for standalone and hybrid ESS projects. These amendments facilitated a faster and more predictable pathway for connecting storage assets to the transmission and distribution networks (AEMC, 2018).
- 2019 – Retailer Reliability Obligation (RRO): The RRO was implemented to maintain system dependability by incentivizing electricity retailers and major customers to contract or invest in firm capacity resources, such as ESS, particularly during peak demand periods (AER, 2019).
- 2019 – Clean Energy Finance Corporation (CEFC) Investment: CEFC has earmarked AUD 300 million to promote grid-scale battery projects, such as the Hornsdale Power Reserve extension and the Victorian Big Battery, offering concessional financing conditions to de-risk early investments (CEFC, 2019).

- 2021 – National Electricity Amendment (FFR-MAS): A new rule introduced Fast Frequency Response Market Ancillary Service (FFR-MAS) to complement existing FCAS. FFR, which provides sub-second frequency control, creates a valuable revenue stream for fast-responding battery storage systems (AEMO, 2021).
- 2021 – AEMO's Storage Integration Guideline: AEMO introduced detailed technical requirements for ESS grid connection, particularly for hybrid configurations integrating wind, solar, and storage. These guidelines aim to standardize performance expectations and streamline project development (AEMC, 2021).
- 2022 – Wholesale Demand Response Mechanism (WDRM): The WDRM allowed large energy users and aggregators, including storage operators, to offer demand-side flexibility into the wholesale market. It opened new opportunities for storage assets to provide grid services by charging/discharging during system stress periods (AEMO, 2021).
- 2024 – ARENA's Advancing Renewables Program (ARP): AUD 70 million was allocated in a competitive financing round by the Australian Renewable Energy Agency (ARENA) to facilitate the installation of grid-scale batteries with cutting-edge inverters and other associated technology (ARENA, 2024).
- 2024 – National Battery Strategy: This comprehensive strategy includes AUD 523.2 million in funding under the Battery Breakthrough Initiative to support local battery manufacturing, with an additional AUD 20.3 million allocated to the "Building Future Battery Capabilities" program. It seeks to boost Australia's competitiveness in battery value chains and secure domestic supply (Australian Government, 2024).

Market structure and grid operation

A tripartite framework governs Australia's National Electricity Market (NEM), which encompasses five states. The Australian Energy Market Commission (AEMC) sets the market's regulatory structure. The Australian Energy Market Operator (AEMO) acts as both the market and system operator, overseeing day-to-day operations and stability. Additionally, the Australian Energy Regulator (AER) oversees compliance and enforcement, ensuring that set rules and regulations are followed. Transmission and distribution are operated by entities like Powerlink (Queensland), AusNet (Victoria), TransGrid (NSW), and ElectraNet (South Australia).

Figure 8: Australia's power market operation

Source: (AEMC, 2025)

Compensation mechanisms and business models

The National Electricity Rules, which form the basis of the NEM, are created and modified by AEMC. As system operator, AEMO is responsible for maintaining system reliability and security in compliance with the requirements established by the National Electricity Law, National Electricity Rules, and the AEMC (AEMO, 2025):

- Energy Arbitrage: Storage systems generate market-based income by charging when electricity costs are low and discharging when prices are high.
- Frequency Control Ancillary Services (FCAS): Batteries participate in regulation and contingency FCAS markets to provide grid frequency support and receive service payments.
- Fast Frequency Response (FFR): New market introduced for sub-second frequency services, offering additional value for fast-responding storage systems.
- Revenue Certainty via Minimum Fixed Price: The NSW Long-Term Energy Service Agreements (LTESAs) give a top-up for LDES if revenues fall below a predetermined level, as well as a sharing of upside revenue over a target (AEMO, 2024).
- Retailer Reliability Obligation (RRO): Retailers are incentivized to contract or invest in firm capacity (including storage) to meet peak demand and reliability targets.
- Network Support Services: Batteries are contracted by distribution or transmission operators to defer network upgrades or manage congestion.

- Wholesale Demand Response (WDR): Storage operators can offer demand-side flexibility into the wholesale market and receive payments for reducing net demand.
- Virtual Power Plants (VPPs): Aggregated residential and commercial batteries participate in energy and FCAS markets through VPP programs.

Business models:

- Merchant projects: Operate based on market earnings (e.g., Neoen's Hornsdale battery).
- Co-located solar + storage: Provides energy smoothing and increased grid participation.
- Aggregator-led VPPs: Companies like Tesla, AGL, and Reposit Power combine residential batteries to offer grid services.

Australia's NEM features one of the most sophisticated FCAS structures globally. The NEM procures a suite of FCAS products, including FFR-MAS, enabling BESS to compete and be compensated for both availability and energy delivered while providing frequency correction and contingency response (woodmac, 2024).

Australia has taken significant steps to integrate ESS into its power market through progressive regulatory reforms, market design innovations, and targeted public funding. These measures have positioned ESS as a basis for enabling system reliability, renewable integration, and frequency stability within a high-VRE context.

KEY TAKEWAYS

- **Australia strategically forecasts the future need for 6–19 GW of dispatchable resources, including large-scale BESS and PSP, by 2040. This forward-looking approach provides a clear roadmap for investment in grid modernization and RE integration.**
- **The National Electricity Market operates under a tripartite governance framework - AEMC (rule-maker), AEMO (system operator), and AER (regulator). This integrated structure supports the seamless deployment and operation of energy storage across the market.**
- **Australia has developed smart regulations that enable ESS to participate effectively in the electricity market. Reforms such as the FCAS Reform and NER Amendments have expanded their roles in providing crucial ancillary services and streamlining grid connections. The WDRM further enhances market flexibility.**
- **Financial mechanisms such as the RRO, LTESAs, and CEFC investments ensure revenue certainty and de-risk early energy storage deployments. These measures actively incentivize the procurement of firm capacity to enhance system reliability.**

CASE STUDY

HORNSDALE POWER RESERVE (HPR)

AUSTRALIA

HPR is one of the world's largest lithium-ion battery energy storage system, with the power output capacity of 150 MW and energy storage capacity of 193.5 MWh.

HPR is a sustainable energy storage solution which stabilizes National Energy Market (NEM) of South Australia and balances grid system by charging its batteries with available surplus energies and supply back to the grid when demand goes high.

CURRENT STATUS Operational since 2017

CONTEXT

- In September 2016, a state-wide blackout triggered by extreme weather revealed South Australia's vulnerabilities regarding high renewable penetration, low system inertia, and limited fast-response frequency control. This event highlighted the need for fast-acting, flexible grid-scale assets to provide frequency control, system security, and resilience during contingency events.
- Consequently, the South Australian Government selected Neoen and Tesla to develop Australia's first grid-scale battery storage project - HPR, co-located with Neoen's 316 MW Hornsdale Wind Farm.
- The project aimed to improve grid stability, minimize blackout risks, and increase market competition – placing downward pressure on electricity prices while enabling higher penetration of renewable energy.

TOTAL COSTS

AUD 71 Million

STAKEHOLDERS

Government of South Australia,

Neoen Australia Pty. Ltd. - owner and operator,

Tesla Motors Australia Pty Ltd – supplier

FUNDING SOURCES

Government of South Australia, ARENA, Neoen Australia Pty. Ltd, Clean Energy Finance Corporation (CEFC)

ACTIVITIES

The HPR project was executed in two phases:

- Phase -1 commissioned on 1 December 2017, with a nameplate capacity of 100 MW / 129 MWh in less than 6 months from inception to operation. Owned and operated by Neoen and maintained by Tesla, the facility comprises 792 Tesla Powerpacks, 189 inverters, and 33 transformers and connected to ElectraNet's 275 kV network. The contracting structure dedicates 70 MW / 10 MWh to the South Australian Government for grid security, while 30 MW / 119 MWh participates freely in the NEM for trading and ancillary services.
- In November 2019, Neoen in collaboration with the South Australian Government, ARENA, and the CEFC, announced the Hornsdale Power Reserve Expansion (HPRX), adding 50 MW / 64.5 MWh in 2020 to reach a total capacity of 150 MW / 193.5 MWh. Supported by AUD 15 million from the South Australian Government's Grid Scale Storage Fund and an AUD 8 million ARENA grant, this expansion aimed to demonstrate advanced grid services including synthetic inertia, enhanced FCAS capability, and improved system protection schemes.
- HPR provides comprehensive services to the South Australian grid and NEM, including Energy Arbitrage, Peak Shaving, and Load Shifting alongside critical ancillary services such as Regulation, Contingency, and Very Fast FCAS, NLCAS, and SRAS.
- Utilizing Virtual Machine Mode since July 2022, HPR provides up to 3,000 MW-seconds of synthetic inertia to mimic synchronous machines, while the 2023 upgrade to Wide Area Protection Scheme ensures faster, accurate, and proportionate responses during system disturbances.

IMPACTS

AT LOCAL LEVEL

- Provides 63,594MWh of clean energy per annum to 13,073 homes across South Australia.
- Prevented blackouts in South Australia through fast response to frequency disturbances, preventing load shedding during islanding events
- Generated ongoing revenues, with expected income of around AUD 4.4 million per annum, with higher earnings driven by ancillary services.
- Full-time equivalent employment generation, which includes 6 onsite and 59 indirect jobs in the Yorke & Mid North Region.

AT COUNTRY LEVEL

- Increased market competition, with 30 MW capacity bid directly into the NEM, exerting downward pressure on energy prices and reducing the pricing impact of local supply constraints
- Reduced average regulation FCAS costs by more than 90% (from AUD 470/MWh to less than AUD 40/MWh) resulting in substantial savings in the NEM.
- Reduced FCAS costs, with an estimated $116 million savings in 2019 alone through the provision of ancillary services.

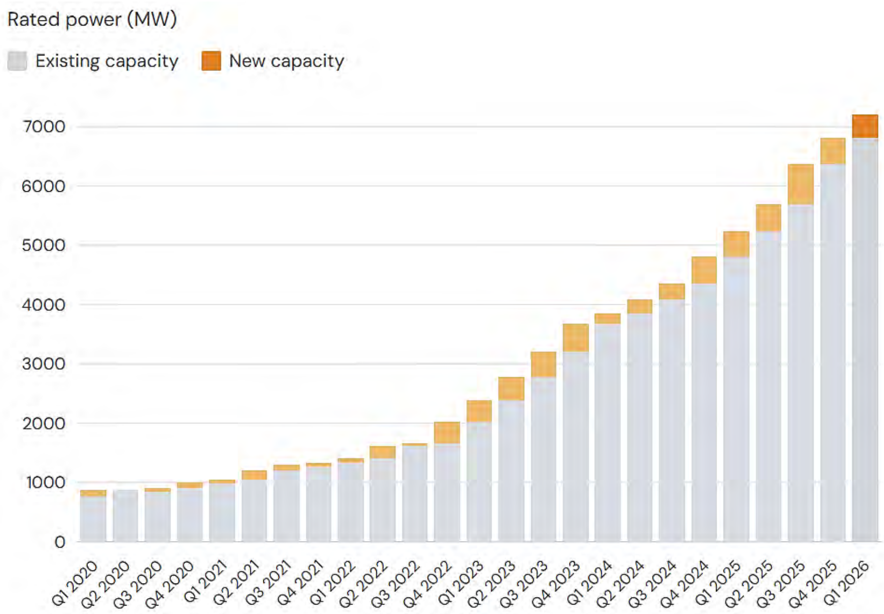
Website: https://hornsdalepowerreserve.com.au

UNITED KINGDOM

The United Kingdom (UK) is undergoing a major energy transition driven by its Net Zero 2050 commitment and the goal of a fully clean power system by 2030. ESS, especially BESS, play a pivotal role in integrating variable renewables, enhancing grid flexibility, and reducing fossil fuel dependency. With installed BESS capacity growing from demonstration scale to 4.5 GW by 2024 and targets of 23–27 GW by 2030, the UK has emerged as a global leader. This transformation is supported by a dynamic policy and regulatory landscape, backed by both national ambitions and international pledges like the COP29 Energy Storage Goal.

In Q1 2026, 397 MW of batteries started commercial operations in the U.K., boosting total energy capacity to 7.2 GW with the construction of new facilities. By the end of Q1 2026, the average battery duration in the U.K. was 1.63 hours, due to financial guarantees for large-scale storage.

Figure 9: U.K.'s ESS Market



Source: [Modo Energy]() *(2026)*

Policy and regulatory frameworks

- 2011 - UK Renewable Energy Roadmap: The UK highlighted challenges in integrating RE generation and the need for balancing solutions, indicating the role of energy storage. Early innovation schemes were launched, including R&D funding for technologies like large-scale liquid air storage. These efforts laid the foundation for future storage support (U.K. Renewable Energy Roadmap, 2011).

- 2012 - Energy Storage Technology Demonstration Competition: The UK identified energy storage as a strategic innovation priority. Department of Energy and Climate Change (DECC) launched a £17 million competition to support R&D and pilot projects, including Moixa's domestic batteries, REDT's flow battery, and EV battery reuse (U.K. Government, 2014). Ofgem also funded UK Power Networks' 6 MW/10 MWh Smarter Network Storage (SNS) project with £13.2 million, marking early government investment in proving and scaling storage technologies (ESA, n.d.).

- 2013 - Energy Act 2013: The 2013 Electricity Market Reform introduced the Capacity Market, enabling storage to participate in capacity auctions. While early battery projects secured long-term contracts, later short-duration systems received lower de-rating factors due to limited duration (U.K. Government, 2013). The initiative reflected early policy recognition of storage's role in a low-carbon system and its long-term economic value.

- 2014 - Initial Large-Scale Battery Deployment and Regulatory Attention: The UK deployed its first large-scale batteries with DECC support, including Highview's 5 MW liquid air system. UK Power Networks commissioned the 6 MW Leighton Buzzard battery for multi-service use. Limited battery participation in the first Capacity Market auction led Ofgem and Business, Energy and Industrial Strategy (BEIS) to review regulations for storage's dual role as generation and demand (ESA, 2025).

- 2015 – NIC Smart Power Report and Parliament Briefings: The UK recognized energy storage as a strategic technology, supported by falling costs, growing renewables, and initiatives like Power Responsive, to encourage demand response and storage participation in balancing markets (U.K. Government, 2018). The National Infrastructure Commission (NIC) highlighted its role in grid flexibility. However, barriers such as high costs, regulatory ambiguity, and double charging were identified. Market and contractual constraints limited investment, despite pilots like Highview's 5 MW project, reinforcing the need for regulatory reform (Energy Storage, 2015).

- 2016 - Call for Evidence on a Smart, Flexible Energy System: The UK initiated major regulatory consultation on storage through the BEIS-Ofgem Call for Evidence, targeting barriers like licensing and double charging (U.K. Government, 2017). NIC emphasized removing policy constraints by 2017. National Grid's Enhanced Frequency Response auction awarded 201 MW solely to battery projects, confirming competitiveness, enabling new entrants, and supporting future revenue stacking models (Informa Markets, 2016).

- 2017 - Smart Systems and Flexibility Plan 2017: Ofgem introduced Smart Systems and Flexibility Plan highlighting key reforms to remove barriers for energy storage, including legal recognition under the Electricity Act, network charge reforms, and market access for aggregated assets. Storage was classified as generation for regulatory purposes, with licensing required above 50 MW (U.K. Government, 2017). Distribution Network Operator (DNO) ownership was restricted to maintain market neutrality. The plan positioned storage as a priority area under the UK's Industrial and Clean Growth Strategies.

- 2018 - Smaçrt Systems and Flexibility Plan - Progress Update: BEIS and Ofgem delivered key regulatory milestones from the 2017 Plan. A modified generation licence formally defined storage and exempted it from final consumption levies. DNOs were prohibited from owning storage to uphold market neutrality (U.K. Government, 2018). Clarifications enabled co-location of batteries with renewables without subsidy loss. These actions strengthened investor confidence through clear and consistent treatment of storage.

- 2019 - Planning and Licensing Reforms: Government initiated planning reforms to eliminate the 50 MW cap on storage projects, enabling larger deployments. BEIS committed to amending planning rules, resulting in secondary legislation (Solar Power Portal, 2020). Ofgem concurrently advanced storage licensing by formally defining electricity storage and introducing dedicated licence conditions. These reforms resolved key regulatory barriers and supported the scale-up of battery energy storage (Ofgem, 2020).

- 2020 – Storage Licensing Decision, Infrastructure Planning, and Energy White Paper 2020: The UK finalized critical reforms enabling large-scale battery storage. Ofgem approved licence changes to define storage and eliminate double charging of final consumption levies (Ofgem, 2020). Simultaneously, the Infrastructure Planning Order exempted BESS projects above 50 MW in England from NSIP, easing local permitting. National Grid ESO launched Dynamic Containment, creating new market value for storage. Policy documents reinforced storage's role in enabling net-zero and flexibility (U.K. Government, 2020) and (U.K. Government, 2020).

- 2021 - Smart Systems and Flexibility Plan 2021 and Large-Scale Long Duration Electricity Storage Call: The Smart Systems and Flexibility Plan 2021 reaffirmed the UK's commitment to removing regulatory barriers and reforming markets for grid flexibility. Focus areas included consumer-side flexibility, grid access, market design, and monitoring (U.K. Government and Ofgem, 2021). A parallel call for evidence on Large Scale Long Duration Electricity Storage (LLES), sought views on how to support emerging long-duration storage technologies such as pumped hydro, flow batteries, and hydrogen storage that cannot easily derive sufficient revenue from existing markets (U.K. Government , 2022).

- 2022 - British Energy Security Strategy: British Energy Security Strategy (April 2022) identified

Long-Duration Electricity Storage (LDES) as essential for a secure, renewable-based grid. It committed to developing policy and regulatory models for LDES by 2024 (British energy security strategy, 2022). The strategy initiated the Review of Electricity Market Arrangements (REMA) process to explore market reforms supporting flexibility. The Energy Security Bill introduced a statutory definition of electricity storage, marking its formal inclusion in primary legislation.

- 2023 – Energy Act 2023: The amended Electricity Act to formally define electricity storage as a subset of generation, aligning statutory law with earlier licensing reforms. Small-scale storage retained existing licence exemptions. A Cap-and-Floor mechanism was proposed to support LDES, targeting technologies like pumped hydro. Operational battery capacity exceeded 4 GW, with policy momentum driving further market development. Parliamentary reports urged swift implementation of LDES support to meet 2035 decarbonization targets (Energy Act, 2023).
- 2024 - Clean Power Action Plan 2030: The Clean Power 2030 Action Plan targets a sixfold increase in battery storage capacity, aiming for 23-27 GW by 2030. It positions batteries as the primary source of grid flexibility in a high-renewables system. The plan supports this through regulatory reform and potential long-term contracting mechanisms. Early progress is evident, with 5.5 GW operational and 20 GW in advanced development by 2025 (Energy Act, 2023).
- 2025 - Cap and Floor Regime for Long Duration Electricity Storage: In March 2025, the UK government and Ofgem published the Technical Decision Document outlining cap-and-floor revenue support for long-duration storage, guaranteeing revenue floors and capping profits (Ofgem, 11 March 2025).
- 2025 - Cap and Floor Regime for Long Duration Electricity Storage: The Cap and Floor design developed by Ofgem aims to unlock investment in LDES by providing revenue certainty while protecting consumers. It proposes a hybrid model with soft caps and floors to preserve market incentives. Key design elements such as contract duration, capital recovery, and assessment periods are adapted from the interconnector regime but tailored to LDES operational characteristics (U.K. Government, 2025).

Market structure and grid operation

The UK power sector follows an unbundled, liberalized market structure. Energy storage assets operate in a competitive framework alongside generation and flexibility providers. Key entities include NG ESO, electricity market operator ELEXON, DNOs, aggregators, and independent storage developers. NG ESO manages real-time system balancing and procures ancillary services. ELEXON oversees market settlement under the Balancing and Settlement Code (BSC) (Energy storag - Update, 2020).

In the wholesale electricity market, energy storage operators engage in arbitrage by charging during low-price periods and discharging at peak demand. They participate in day-ahead, intraday, and real-time markets. ESS units are registered with both generation and demand IDs to reflect bidirectional flows. Increasing price volatility from renewable generation enhances arbitrage value. Many operators partner with optimizers or trading firms to manage market exposure efficiently. The balancing mechanism provides additional revenue by enabling real-time dispatch by NG ESO (U.K. Government, 2025).

DNOs do not own or operate storage due to regulatory restrictions but act as facilitators. They procure location-specific flexibility via auctions to manage local constraints (U.K. Government, 2018). Aggregators enable smaller or distributed ESS (including residential and EV-based systems) to participate in national markets. They bundle resources into Virtual Power Plants and operate under the "Virtual Lead Party" framework, increasing market access and competition (Elexon, 2025). This structure ensures energy storage can participate across national and local markets for grid support and commercial optimization.

In summary, the UK's ESS market enables storage participation through competitive mechanisms, with ESO and DNOs procuring services but not owning assets. Storage is legally classified as generation, with neutral network operators and active third-party developers. This structure supports rapid battery deployment and efficient system integration.

Compensation Mechanism and Business Models

- Capacity Market (CM): The UK Capacity Market ensures revenue for ESS by compensating them for availability during system stress events. New-build ESS can secure contracts for up to 15 years via competitive

auctions, while existing ones receive shorter terms (U.K. Government, 2014). It offers revenue stability, supporting investment in storage.

- Balancing Services: NG ESO procures balancing services such as Frequency Response (FFR), Dynamic Containment (DC), and Reserve from ESS. These services provide fast-response support for frequency stabilization and grid resilience. ESS providers are compensated based on service performance, availability, and bid prices in daily auctions (National Energy System Operator, 2025).

- Wholesale Market Arbitrage: ESS can participate in the wholesale electricity market by charging during low-price periods and discharging when prices are high known as arbitrage. This market-based mechanism allows ESS to generate profit by responding to price signals, often with support from aggregators or trading platforms (U.K. Government, 2023).

- Distribution Use of System (DUoS) Flexibility Payments: DNOs procure flexibility services from ESS to manage local network constraints, defer reinforcement costs, and enhance local reliability (Ofgem, 2025). ESS assets earn payments by participating in flexibility tenders managed via leading end-to-end market platforms. This is a growing avenue for distributed and community-level storage (U.K. Power Networks, 2024).

Business Model (Energy storage - Update, 2020)

- Independent Project Developers (Third-Party Ownership): Independent power producers and infrastructure funds dominate UK ESS deployment. Projects are financed via equity and debt, with revenues stacked across Capacity Market, ancillary services, arbitrage, and balancing. Market participation is managed through optimizers or aggregators under contracts offering revenue floors and shared upside, enabling bankable cash flows and risk transfer.

- Behind-the-Meter (BTM) Storage Models: BTM storage is deployed at customer sites industrial, commercial, or residential for peak shaving, tariff optimization, and backup. While driven by cost savings, many BTM assets also participate in flexibility markets via aggregators. Though smaller in scale, BTM contributes valuable distributed flexibility and benefits from tariff reform and policy enablers.

- Revenue Stacking and Flexibility Aggregation: Most ESS projects in the UK rely on revenue stacking across short-term contracts and volatile market-based income. Aggregators or optimizers manage dispatch under offtake agreements that include floor payments and performance-based sharing. These structures de-risk merchant exposure and have become key to securing project finance.
- Public-Private Partnerships and Government Support: The UK has supported ESS via innovation grants, network-funded pilots, and is now advancing PPP models such as cap-and-floor and RAB for long-duration storage. These instruments offer minimum revenue guarantees to unlock investment in capital-intensive technologies. Capacity auctions serve as additional long-term contracting mechanisms.
- Hybrid BTM with Energy Trading: In this model, providers install ESS at customer sites and earn through market participation. Hosts benefit from bill savings, while providers optimize flexibility revenues. This model resembles Energy Service Company's arrangements and supports distributed Virtual Power Plant (VPP) formation, expanding market access for small-scale storage.

In the UK, BESS participation in electricity markets is increasingly linked to market-driven pricing structures that remunerate storage for system services. Storage assets participate in capacity mechanisms and ancillary service markets (such as Frequency Response and Balancing Services), where revenues are determined through market clearing price (Brown, 23 September 2025).

UK ESS business models emphasize revenue stacking, risk-sharing, and aggregator-enabled market access. With limited direct subsidies, private investment is driven by optimized multi-market participation. Policy tools like capacity payments and cap-and-floor schemes are critical to scaling both short- and long-duration storage as bankable assets.

KEY TAKEWAYS

- **The UK has progressively reformed its regulatory framework since 2011, formally classifying storage as generation, removing double charging, and enabling co-location with renewables, creating a clear legal and market pathway for ESS deployment.**
- **Storage projects derive viability through multi-market participation stacking revenues from Capacity Market contracts, frequency services, wholesale arbitrage, and DNO flexibility tenders ensuring financial sustainability and investment confidence.**
- **To address the specific challenges of long-duration storage, the UK introduced a Cap-and-Floor mechanism in 2025, offering partial revenue certainty for technologies unable to compete on short-term market signals alone.**
- **Aggregators enable distributed ESS, including BTM and EV-based systems, to access national markets through virtual aggregation models, enhancing system-wide flexibility and competition.**
- **A neutral, liberalized market structure where ESO and DNOs procure but do not own ESS has accelerated private-sector participation and improved the efficiency of grid service procurement.**

CASE STUDY

LONG DURATION ELECTRICITY STORAGE (LDES) CAP AND FLOOR REGIME, UNITED KINGDOM

UNITED KINGDOM

The Cap and Floor regime provides revenue certainty to eligible LDES projects by establishing a minimum revenue level (floor) and a maximum revenue level (cap) over a standard 25-year period.

The UK Government formally adopted the LDES Cap and Floor mechanism in October 2024 and appointed Ofgem as the delivery body and regulator for the scheme.

CURRENT STATUS:
Operational since March 2025

CONTEXT

- As the United Kingdom transitions towards a low-carbon electricity system under its Clean Power 2030 Action Plan and Net Zero 2050 commitments, increasing deployment of renewable energy sources such as offshore wind and solar has created a growing need for flexible, dispatchable storage resources capable of balancing supply and demand over extended periods.
- Despite the recognized value of Long Duration Electricity Storage (LDES), deployment of new projects has remained limited due to high capital costs, long construction periods, technology risks, and uncertain future revenue streams.
- To address these barriers, the UK Government announced in October 2024 the introduction of a Cap and Floor investment support mechanism for LDES, based on the successful regulatory model previously used for electricity interconnectors. The regime is administered by Ofgem and is designed to stimulate investment while protecting consumers from excessive costs.
- If project revenues fall below the floor, consumers provide support through regulated network charging arrangements.
- Conversely, when revenues exceed the cap, excess revenues are returned to consumers. The mechanism seeks to balance investor confidence with consumer protection while accelerating deployment of strategically important storage infrastructure.

TARGET LDES CAPACITY

2.7 to 7.7 GW by 2035

STAKEHOLDERS

Department for Energy Security and Net Zero (DESNZ)

Ofgem – Regulator for the electricity market

National Energy System Operator (UK)

FUNDING SOURCES

Debt financing, Private sector equity investment, Institutional investors and infrastructure funds

ACTIVITIES

The Technical Decision Document, jointly issued by DESNZ and Ofgem in March 2025, established the detailed framework for implementation. Key features of the regime include:

- The Technical Decision Document, jointly issued by DESNZ and Ofgem in March 2025, established the detailed framework for implementation. Key features of the regime include:
  - A 25-year revenue support period for successful projects.
  - A minimum storage duration requirement of 8 hours at full discharge capacity.
  - Minimum project capacity thresholds of 100 MW for commercially mature technologies (Track 1) and 50 MW for emerging technologies (Track 2).
  - Technology-neutral participation covering lithium-ion batteries, pumped storage hydro, compressed air energy storage, liquid air energy storage, vanadium flow batteries, zinc batteries, iron-air batteries and hybrid storage configurations.
  - A two-stage assessment process comprising Eligibility Assessment and Project Assessment (Cost Benefit Analysis and Cost Assessment).
  - Revenue support through a regulated cap and floor mechanism administered by Ofgem.
- The first application window opened on 8 April 2025 and closed on 9 June 2025. A total of 171 project applications representing 52.6 GW of discharge capacity were submitted. Following eligibility assessment, 77 projects with a combined discharge capacity of 28.7 GW progressed to the Project Assessment Stage. These include:
  - 48 Lithium-ion Battery Energy Storage System (BESS) projects totaling 20.2 GW.
  - 5 Pumped Storage Hydro projects totaling 4.6 GW.
  - 21 Flow Battery projects (Vanadium Flow and Vanadium/Zinc technologies) totaling 3.5 GW.
  - 2 Liquid Air Energy Storage (LAES) hybrid projects totaling 0.4 GW.
  - 1 Compressed Air Energy Storage (CAES) project totaling 0.1 GW.
  - The programme follows a twin-track approach: (a) Track 1 projects targeted for delivery by 2030 and (b) Track 2 projects targeted for delivery by 2033.

IMPACTS

AT LOCAL LEVEL

- Unlocks investment in large-scale energy storage projects, creating construction and operational employment opportunities.
- Supports development of domestic battery manufacturing, engineering, and energy infrastructure supply chains.
- Strengthens local grid resilience and reliability through enhanced balancing and reserve capabilities.
- Enables higher utilization of local renewable energy generation by reducing curtailment and congestion.

AT COUNTRY LEVEL

- Mobilizes significant private sector investment in strategic energy infrastructure through long-term revenue certainty.
- Facilitates integration of higher levels of offshore wind and solar generation.
- Enhances energy security and system flexibility by providing dispatchable storage capacity.
- Creates a technology-neutral pathway for deployment of multiple long-duration storage technologies, reducing reliance on any single technology solution.

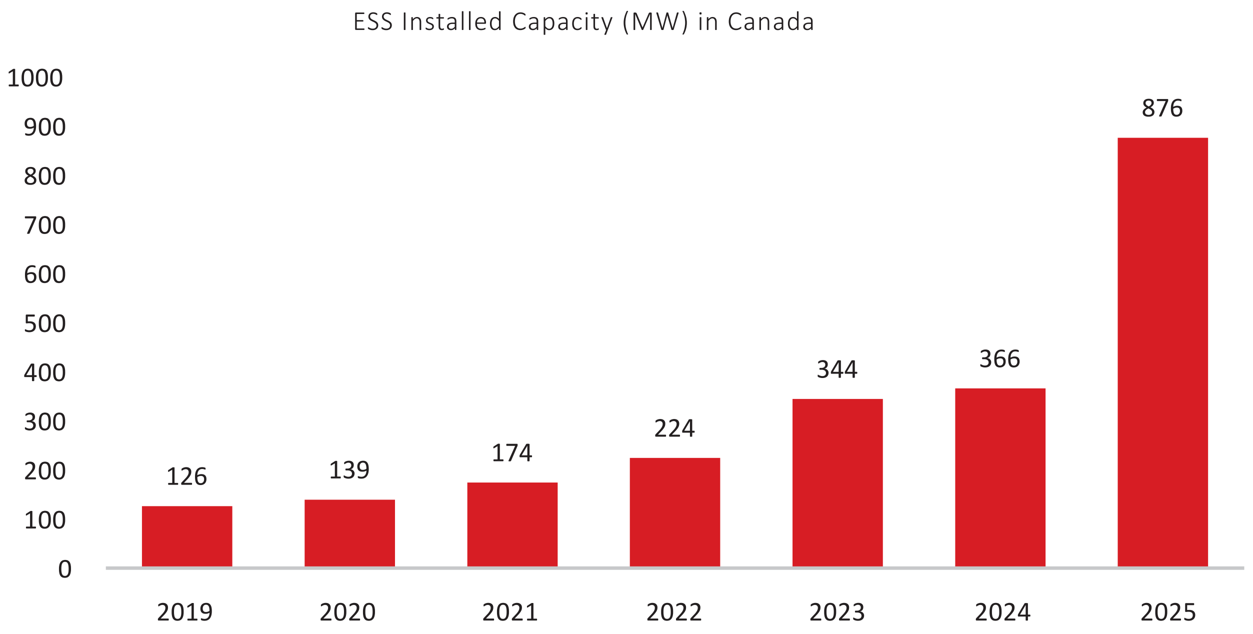
Website: https://www.ofgem.gov.uk/sites/default/files/2025-03/Long%20Duration%20Electricity%20Storage%20Technical%20Decision%20Document.pdf

CANADA

Canada currently has ~1 GW of energy storage capacity and is targeting 8–12 GW by 2035 to meet net-zero goals. Canada's energy storage policy framework is governed by a model in which the federal government sets broad targets and incentives while provinces control implementation, resulting in diverse regional models. The Quinte Compressed-Air Energy Storage (CAES) System, located in Greater Napanee, Ontario with 500 MW capacity is the largest in Canada.

According to the Canada Energy Regulator, Canada's grid-connected energy storage capacity (>1 MW) could rise to 1,149 MW by 2030 based on 12 projects under construction. If an additional 27 approved projects are built, total capacity could reach 2,768 MW by 2030. BESS is the fastest growing and most widely deployed storage technology in Canada, with nearly all projects planned by 2030 using batteries, alongside a few Compressed Air Energy Storage (CAES) and Pumped Hydro Storage (PHS) projects.

Figure 10: Canada's ESS Market



Source: Canadian Renewable Energy Association (2026)

Policy and regulatory frameworks

- 2018 – Creation of the Energy Storage Advisory Group: The Independent Electricity System Operator (IESO) established the Energy Storage Advisory Group (ESAG) in 2018 to advise, support and assist the IESO in evolving policy, rules, processes and tools to better enable the integration of storage resources within the current structure of the IESO-administered market (IESO, 2025).
- 2019 – Alberta Electric Storage Operator (AESO) released its Energy Storage Roadmap, outlining plans to integrate storage technologies into its Authoritative Documents, grid, and market systems (Energy Storage Roadmap, 2019).
- 2021 – Canadian Renewable Energy Association (CanREA)'s 2050 Vision, "Powering Canada's Journey to Net-Zero" stipulates that Canada must rapidly expand its deployment of wind energy, solar energy and energy storage to reach net-zero GHG emissions by 2050 (CanREA, 2021).
- 2021 – Smart Renewables and Electrification Pathways program (SREPs) was announced by the Natural Resources Canada (NRCan) to support Canada's goal of reaching net-zero emissions by 2050 by providing federal funding to grid modernisation projects including ESS. In 2024, the government announced $500 million in funding for SREPs Utility Support

Stream to encourage federal funding for infrastructure projects including storage (CER, 2025).

- 2022 – Ontario's Independent Energy Service Operator (IESO's) Pathways to Decarbonization report set a target for Ontario to procure up to ~2,500 MW of energy storage (primarily battery-based) by 2027 and led to the development of Powering Ontario's Growth Plan (ERO, 2023).
- 2023 – Powering Ontario's Growth Plan was launched which led to competitive procurement of 1784 MW energy storage through Long-Term 1 Request for Proposals (LT1 RFPs) (IESO, 2023).
- 2023 – Canadian Net-Zero Emissions Accountability Act: An Act respecting transparency and accountability in Canada's efforts to achieve net-zero greenhouse gas emissions by the year 2050 (Canadian Net-Zero Emissions Accountability Act, 2021).
- 2023 – Canadian Federal Budget 2023 introduced a 30% refundable Clean Tecnology (CT) Investment Tax Credits (ITC) for clean energy technologies, including battery storage, providing upfront cash support, improving bankability, and de-risking early projects. The 2023 Federal Budget added two more supportive credits: a 30% Clean Tech Manufacturing ITC and a 15% Clean Electricity ITC, both applicable to battery and other storage technologies. Additionally, the Budget also made provisions for Indigenous Loan Guarantee Program to incentivise storage projects and reducing diesel reliance in these communities roughly $6.9 billion from 2023-2024 to 2027-2028 (Canada ER, 2025).
- 2023 - The government of Nova Scotia launched the 2030 Clean Power Plan (Clean Power Plan, 2023) with a target to deploy between 300 MW and 400 MW of battery storage by 2030 (Clean Power Plan, 2023). As of February 2024, the Canada Infrastructure Bank announced a $138.2 million commitment towards the storage project to be developed by Nova Scotia Power.
- 2024 – The federal Clean Electricity Regulations (CER), finalized in 2024 (coming into force 2025), aim for a net-zero electricity grid by 2050, providing flexibility for provinces to leverage regional strengths, including battery storage (Clean Electricity Regulations, 2024).
- 2024 – The government announced $500 million in funding for the Smart Renewables and Electrification Pathways program (SREPs) Utility Support Stream to encourage investments in infrastructure including energy storage (CER, 2025).
- 2024 – Ontario's DER Market Vision allows energy resources as small as 100 kW—such as rooftop solar, battery storage, and EVs—to be aggregated and participate in wholesale markets.
- 2025 – Ontario's Market Renewal Program (2025) aims to transform the wholesale markets introduced day-ahead market, locational (nodal) pricing, enhanced real-time dispatch, and a capacity auction, unlocking varied revenue streams for ESS (IESO, n.d.).

INNOVATIVE PROJECTS AND APPROACHES ON ESS

Ontario concluded the largest battery storage procurement in Canada's history in 2024 by procuring 2195 MW of capacity under the competitive procurement mechanism in line with Powering Ontario's Growth Plan (MoEE, 2023). Ontario has initiated pre-development of the 1 GW Meaford Pumped Storage Project, highlighting pumped hydro's role as a key long-duration storage solution in Canada's grid-scale portfolio (Ontario, 2025)Ontario is home to Canada's two largest energy storage facilities - the Oneida battery project (250 MW) which is co-owned by indigenous communities, and the Compressed-Air Energy Storage (CAES) system in Greater Napanee (500 MW). Underneath the Interoperability and Non-Wires Alternative Demonstration, Ontario's IESO and Alectra Utilities have piloted Non-Wires Alternatives (NWAs) in York Region, using energy storage and other DERs to manage local grid constraints and defer traditional infrastructure upgrades (IESO York Region NonWires Alternatives Demonstration Project. Alectra., n.d.). The project also developed an interoperability framework and market design to enable third-party NWA providers to participate in both distribution- and wholesale-level markets, supported by new protocols for dispatch, communication (Government of Canada., n.d.).

Market structure and grid operation

Canada does not have a single national electricity grid. Canada's electricity is managed provincially, with each region running its own distinct electricity system (RNNR, 2024). Electricity regulation and market structures in Canada vary from a fully deregulated electricity market in Alberta to a hybrid market in Ontario, to regulated and vertically integrated markets in other provinces (the latter entails a single company that may own the generation, transmission, and distribution to deliver electricity to end users at regulated rates).

The Canada Energy Regulator (CER) regulates all electricity exported from Canada but does not regulate electricity import activity into Canada (CER, 2025). Canada and the U.S. have tightly integrated electricity systems, with physically interconnected provincial and state grids. Cross-border trading is facilitated through power markets such as ISO New England (ISO-NE), Midcontinent Independent System Operator (MISO), New York Independent System Operator (NYISO), Northwest Power Pool (NWPP), and PJM Interconnection (Vine, 2017). The map shows Canada's interprovincial high-voltage transmission connections, color-coded provinces highlighting their relative grid interconnectivity indicating where energy storage can support grid reliability, renewable integration, and cross-border electricity trade based on the strength and capacity of these links.

Figure 11: Canada's power market operation

Compensation mechanisms and business models

- One of the primary mechanisms is capacity payments, for example, Ontario's Independent Electricity System Operator (IESO) secures long-term storage capacity, offering fixed payments for ensuring resource adequacy (IESO, n.d.).
- Provinces like Ontario and Alberta permit revenue stacking, allowing ESS to simultaneously participate in multiple revenue streams, such as capacity payments, ancillary services, and energy arbitrage (Energy Storage News, 2023).
- Behind-the-meter storage compensation mechanisms focus on cost avoidance (bill savings through self-consumption), time-of-use (TOU) pricing structures (e.g., in Ontario, British Columbia, and Quebec), and demand charge management (for C&I customers). In Ontario, many C&I consumers use batteries to lower their Global Adjustment (GA) charges (Deign, 2019).
- The Smart Renewables and Electrification Pathways Program (SREPs), launched in 2021 with a $4.5 billion budget, supports energy storage in partnership with provinces, territories, and Indigenous Peoples. It runs until March 2036 (SREPs, 2024).
- Canada has pioneered the Indigenous Loan Guarantee Programme for enabling energy including ESS projects in indigenous communities. (Natural Resources Canada, 2025).

Business models

- Contracted Model enables long-term procurement by Grid Operator through fixed payments resulting in revenue security, for example by IESO in Ontario.
- Merchant Model (Market Participation) allows storage operators to earn revenues directly from wholesale energy, capacity, and ancillary service markets, for example, Alberta (Lev, 2020).
- Utility-owned model, for example, the Matalik BESS is owned and operated by EVLO Energy Storage Inc., is a wholly owned subsidiary of Hydro-Quebec, the provincial public utility of Quebec, earning revenue through regulated utility cost recovery, not capacity auctions (HydroQuébec., 2025).
- Co-ownership model: The 250 MW Oneida Energy Storage facility (Canada's largest), co-owned by Northland Power, NRStor, Six Nations of the Grand River Development, and Aecon Group, serves as a model for prioritizing indigenous involvement in the development of ESS projects in Canada (Northland Power Inc, 2025).
- Inclusive Ownership through Indigenous Equity Participation: Ontario's 2023 energy storage procurement incorporated Indigenous equity partnerships, with multiple selected projects demonstrating at least 50% Indigenous economic participation (IESO, 2023).

Energy storage in Canada (e.g. in Alberta province) is currently subject to the AESO demand transmission service (DTS) tariff for charging and the supply transmission service (STS) tariff for discharging. The Alberta market offers several potential revenue streams for storage market participants, including, but not limited to, energy arbitrage, which allows revenues from charging during low-cost hours and discharging during higher-price hours. Ancillary services also provide opportunities, such as contingency reserve, which is available to storage, and fast frequency response, accessible through bilateral contracts, while regulating reserve is not currently available to storage. Unlike the current block procurement methodology, ancillary services were procured hourly. Additionally, black start services are available through bilateral contracts (Energy and Environmental Economics, Inc., 2024).

Overall, Canada's energy storage landscape is rapidly expanding, driven by diverse provincial policies, supportive federal programs, innovative project models, and multiple revenue streams, positioning BESS as a central component of the country's clean energy and grid modernization strategy.

KEY TAKEWAYS

- **Canada's approach on ESS deployment combines strong federal programs (e.g., Clean Tech ITC, SREPs) with provincial autonomy over implementation through targets, tenders, and regulations. Canada's Indigenous equity and loan guarantee frameworks have enabled and empowered indigenous communities to become co-owners of storage projects, such as the 250 MW Oneida facility**
- **Canada's grid-scale ESS projects benefit from revenue stacking, with access to diverse revenue streams including capacity, energy, and ancillary service markets enhancing both operational flexibility and investment returns.**
- **On the distributed storage front, Ontario's DER Roadmap and Alberta's reforms support C&I BTM storage for managing demand charges, Global Adjustment charges, and TOU pricing, while Canada's DER Market Vision enables market access for aggregated BTM system.**
- **Diverse business models support storage deployment, for example, contracted (IESO procurements), merchant (Alberta's open market), utility-owned (e.g., Hydro-Québec), and co-ownership with Indigenous communities—tailored to each province's regulatory structure.**
- **Canada's electricity system is physically and commercially integrated with U.S. power markets, enabling cross-border trade and balancing.**

CASE STUDY

ONEIDA ENERGY STORAGE (OES)

CANADA

OES Project is Canada's largest operational battery energy storage system, with a power output capacity of 250 MW and energy storage capacity of 1,000 MWh.

A sustainable energy storage solution which stabilizes Ontario's electricity grid and balances the system by charging its batteries with available surplus energies – including wind and nuclear – and supplying it back to the grid when demand is at its peak.

CURRENT STATUS Operational since May 2025

CONTEXT

- Ontario's electricity sector is modernizing to integrate higher penetrations of renewable energy. The system faces challenges with surplus carbon-free energy (wind and nuclear) during off-peak periods and a reliance on gas-fired plants during peak demand.
- This transition highlighted the need for large-scale, fast-acting assets to provide grid balancing services, enhance system reliability, and reduce greenhouse gas emissions from fossil-fuel backups.
- Originally developed as a 50/50 partnership between Six Nations of the Grand River Development Corporation (SNGRDC) and NRStor Inc., the project sets a new Canadian benchmark for Indigenous inclusion and equity in clean energy infrastructure.
- The project aims to drive energy savings and reduce greenhouse gas emissions across the province and provide essential capacity to the Ontario grid.

TOTAL COSTS

CAD 700 Million

STAKEHOLDERS

Northland Power Inc, Six Nations of the Grand River Development Corporation (SNGRDC), NRStor Inc, Aecon Group Inc and Mississaugas of the Credit Business Corporation (MCBC) – Project owners and partners; IESO – System operator

FUNDING SOURCES

Canada Infrastructure Bank, Natural Resources Canada, and Private Equity Partners (Northland Power, SNGRDC, NRStor, Aecon)

ACTIVITIES

The OES project was developed and executed through a long-term contracted model enabled by provincial and federal policy reforms:

- The project officially entered commercial operations in May 2025, achieving completion ahead of schedule and under budget. The facility comprises 278 Tesla battery units and associated power conversion systems, located on a 10-acre site adjacent to existing Hydro One infrastructure.
- To ensure comprehensive risk mitigation, the project utilizes dry-type lithium-ion batteries to minimize leakage and environmental hazards, alongside fire safety and system protection schemes validated through extensive testing and permitting processes.
- The project enables energy arbitrage by storing surplus off-peak electricity from wind and nuclear resources and discharging during periods of peak demand, thereby supporting efficient operation of conventional assets and higher renewable integration.
- The facility operates under a 20-year capacity services contract with Ontario's Independent Electricity System Operator (IESO), ensuring long-term revenue certainty, while also participating in the wholesale market and ancillary services.
- It provides frequency regulation, operating reserves, and system balancing services to the Ontario grid.
- It is designed to participate in Ontario's evolving wholesale markets under the Market Renewal Program, including enhanced real-time dispatch and future day-ahead markets, and is structured to allow revenue stacking across capacity payments, energy market revenues, and ancillary services.
- The project is delivered through a public-private partnership operated by the Oneida Energy Storage Limited Partnership (Oneida LP), a collaboration between Northland Power, SNGRDC, NRStor, Aecon and MCBC.

IMPACTS

AT LOCAL LEVEL

- Indigenous Prosperity will yield at least CAD 1.5 M per year for the Six Nations community over the project's 20+ year lifespan.
- Employment generated over 900,000 hours (~500 FTE) of local employment, during construction and operation period, many through the Indigenous-owned firm A6N Utilities (Aecon-Six Nations JV).
- Community Capacity provided training and long-term maintenance positions for community members, with roughly 15 full-time jobs for the life of the project.

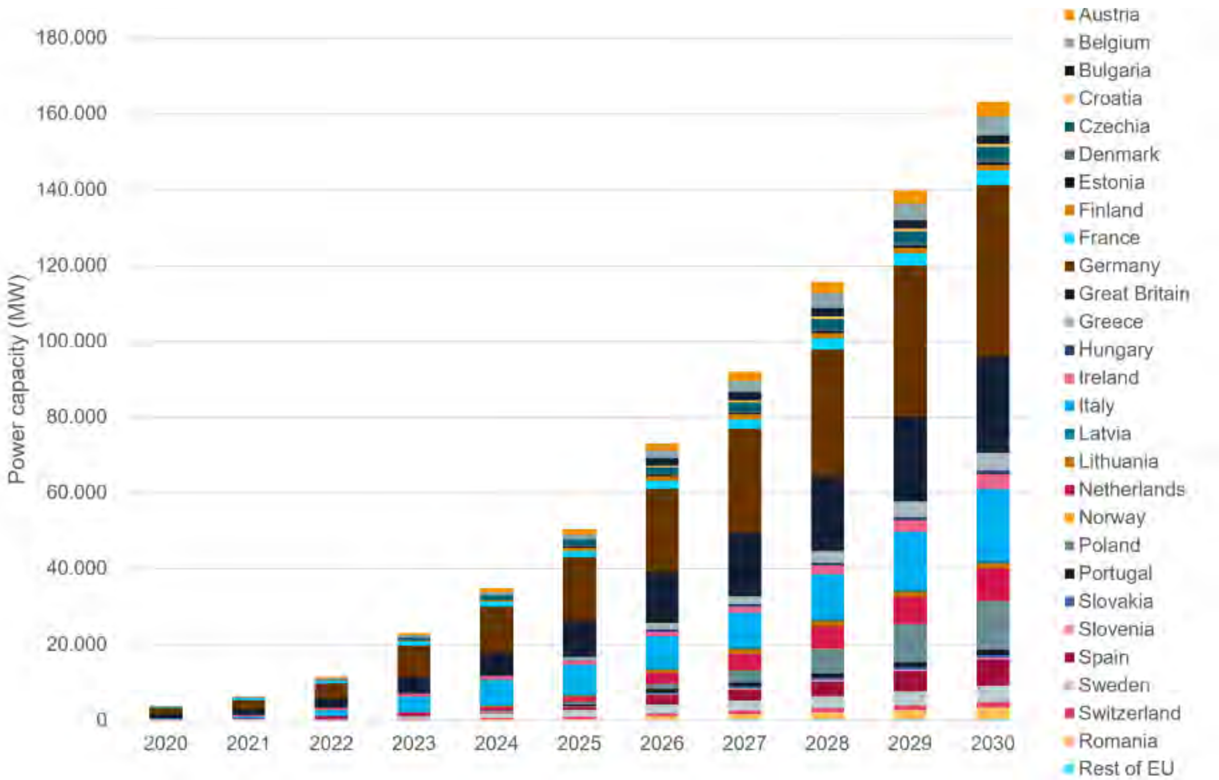
AT COUNTRY LEVEL

- Projected reduction of CO_2 emissions by 4.1 million tonnes over its life, i.e. equivalent of taking 40,000 cars off the road annually.
- Estimated to generate up to CAD 760 million in net savings for Ontario electricity ratepayers.
- Grid Reliability more than doubled Ontario's energy storage capacity, supporting the efficient operation of nuclear and renewable assets while reducing the need for gas-fired "peaker" plants.
- The project demonstrates a replicable model combining long-term capacity procurement, revenue stacking, Indigenous co-ownership, and federal-provincial policy alignment.

EUROPEAN UNION

As of 2024, total storage capacity in the EU, surpassed 89 GW, comprising 35 GW of batteries and 53 GW of pumped hydron with Germany and Italy leading the market. While EU-wide directives provide a common framework (listed below), member states design their own implementation strategies based on national energy mix, grid needs, and policy priorities. The *Cumulative Energy Storage Installed Capacity as of December 2024 is shown in the picture* (pv magazine, 2025).

Figure 12: EU's ESS Market



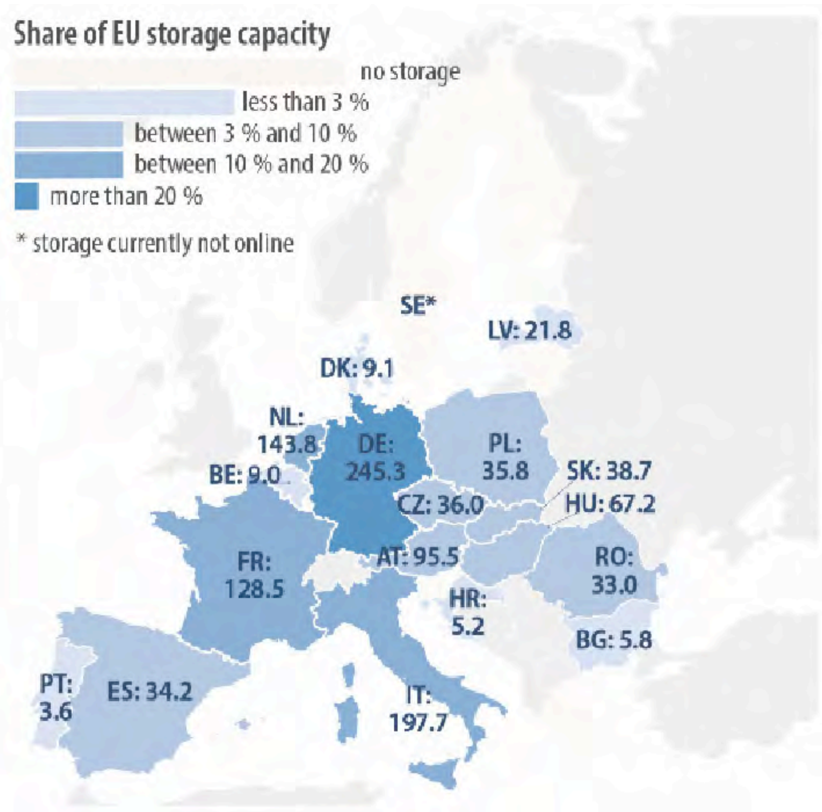
Policy and regulatory frameworks

- 2017 – EU Grid Balancing Guideline (EB-GL) creates a common market for facilitating the exchange of balancing resources between European Transmission System Operators (TSOs) (ENTSOE., n.d.).
- 2019 - Clean Energy for All Europeans Package explicitly recognizes energy storage as a distinct asset class (separate from generation or consumption), supports ESS access to energy markets, defines rights and responsibilities of ESS operators, mandates Member States to assess flexibility needs, setting national targets, and enables ESS participation in capacity markets, ancillary services (Clean Energy Package (CEP), 2025).
- 2019 - EU Electricity Regulation required an enhanced EU-wide adequacy assessment methodology and annual adequacy assessments for determining storage and promotes non-discriminatory access to markets for ESS (EU Regulation, 2019). Under the EU Electricity Regulation, key network codes like the Requirements for Generators (RfG), Demand Connection Code (DCC), System Operation Guidelines (SOGL), and Capacity Allocation and Congestion Management (CACM) ensure harmonisation and interoperability of ESS across Member States by standardizing connection, operation, and market access rules.
- 2020–2022 - European Green Deal (EC, n.d.) and REPowerEU (EC, n.d.) accelerated funding, permitting reforms, and policy focus including both utility-scale and distributed storage. The EU's Recovery and Resilience Facility (RRF), launched in 2021, post COVID, provides state-aid to Member States for ESS projects (EC, n.d.).

- 2022 - The Trans-European Networks for Energy (TEN-E) Regulation, updated in 2022, enables energy storage projects with cross-border impact to be listed as Projects of Common Interest (PCIs), supporting streamlined regulation, EU funding, and grid integration through the Ten-Year Network Development Plan (TYNDP) (EC, n.d.).
- 2022 - EU's Action Plan on the Digitalisation of the Energy System promoted interoperability and data driven infrastructure for storage deployment.
- 2023 - The Temporary Crisis and Transition Framework (TCTF) facilitate investments in energy storage by relaxing state aid rules and is a key component of the Green Deal Industrial Plan (EC, 2023).
- 2023 – European Commission (EC) Recommendations on Energy Storage specified non-binding guidelines urging Member States to conduct flexibility needs assessments, design competitive tenders or capacity mechanisms for storage, and support deployment in islands, remote regions, and behind-the-meter applications (EC, 2023).
- 2023: The EU Batteries Regulation (2023/1542) establishes binding requirements across the battery lifecycle, including carbon footprint disclosure, recycled content thresholds (e.g. 16% cobalt, 85% lead by 2031), performance and durability standards, mandatory battery passport for tracking, and due diligence obligations for raw material sourcing (EU, 2023).
- 2024 – EU Electricity Market Design (EMD) reform recognised ESS role in grid balancing, participation in electricity markets (EC, 2023).
- 2025 - Clean Deal Industrial Plan promotes state-backed funding (through mechanisms like European Investment Bank, Innovation Fund targeting LDES) for ESS technologies via infrastructure upgrades and public procurement (EC, n.d.).
- 2025 - Clean Industry State Aid Framework (CISAF) to ease grants, tax breaks, and low-interest loans for clean technology projects including energy storage (EC, 2025).

EU member states are advancing energy storage policies based on their national circumstances, shaping compensation mechanisms and business models. Leaders like Germany, Italy, France, Spain, Poland, and Portugal have made significant progress, while others—such as the Czech Republic, Hungary, and Bulgaria—have included storage in their NECPs but are still in the early stages of implementation and regulatory development.

Figure 13: Share of EU storage capacity by country



- **Germany** - The Electricity Market Act (Strommarktgesetz) (BMWK, 2016) and Electricity Storage Strategy (BMWK, 2023) enable BESS and PHS integration by removing fees, levies on ESS infrastructure, and preparing storage participation in a future Capacity Market (2028) via Innovation Tender. Energy Industry Act removed double grid fees.
- **France** - The Programmation Pluriannuelle de l'Energie (PPE) supports PHS, behind-the-meter storage, and remote/offshore island applications (Ferracci, 2025). France revised its Storage Methodology in 2023 to include detailed criteria/standards for evaluation of ESS integration and connection costs in non-interconnected zones (ZNIs), emphasising technologies prioritised by PPE. France's Energy Code (White & Case LLP, 2022) legally recognise storage, establishes ESS tender mechanisms and a national registry.
- **Italy** – The National Energy and Climate Plan (Italian acronym PNIEC) and Capacity Market (Mercato della Capacità), funds both utility-scale battery and PHS projects, allowing ESS to provide adequacy and balancing services via tenders. Italy's Superbonus 110% tax credit supports residential BTM battery storage (De Gasperis, 2024).
- **Belgium** - The Federal Energy Strategy Note (2023) support BESS participation in capacity and aFRR markets.
- **Portugal** - The National Energy and Climate Plan 2030 (PNEC 2030) promotes hybrid PV+storage systems, allows co-located storage to participate in auctions, and supports flexibility services.
- **Austria** - promotes pumped hydro storage through the Renewable Expansion Act (EAG), which offers market premiums and investment grants, supported by low-cost loans from the European Investment Bank (EIB) (EIB, 2025).
- **Poland** - Poland's Energy Policy until 2040 (PEP2040) includes storage for renewables integration and frequency control.
- **Greece** - Greek National Recovery and Resiliency Plan (RRP), backed by EU RRF state aid and CfD for 10-year duration (covers operations) enables ESS (EASE, 2024).
- **Czech Republic** - aims to define a regulatory framework for BESS to provide FCR/aFRR services under State Energy Policy (under revision).
- Hungary and Luxembourg - Conducted flexibility needs assessments in line with the 2024 EU Electricity Market Design reform.
- **Nordic Member States** - In the Nordics, most of the wholesale electricity is traded through the Nord Pool power exchange (Lieskoski S. K.S., 2024). As of 2024, fourteen large BESS are operational in Sweden (largest amongst Nordic Member States), providing a combined capacity of 211 MW / 211 MWh (Rayner, 2024). Ancillary markets (Frequency Containment Reserve for Disturbances) have led to BESS surge from 2023-2024. Finland is supporting battery clusters under the National Battery Strategy and has one of the largest 90GWh seasonal thermal energy storage near Helsinki funded by grants, market- based loans (Maisch, 2024).

Market structure and grid operation

The EU's liberalized energy market framework increasingly treats energy storage as a key flexibility asset. Directives like the Electricity Directive (2019) and the Clean Energy Package. The EU electricity market operates on a liberalized, multi-level structure, where generation, transmission, distribution, and supply functions are largely unbundled to promote competition and efficiency. Market operations are coordinated at both national and regional levels, with Transmission System Operators (TSOs) ensuring grid stability and cross-border flows via mechanisms like day-ahead, intraday, balancing, and capacity markets. The ENTSO-E and ACER (Agency for the Cooperation of Energy Regulators) oversee coordination, transparency, and regulation across member states.

However, fragmentation in liberalization remains significant. The European Commission's 2025 Report on the assessment of possibilities of streamlining and simplifying the process of applying a capacity mechanism recommended simplifying capacity mechanism approval via streamlined European Resource Adequacy Assessment (ERAA) methodology and fast-track state aid procedures (EU, 2025). It recognised the need to redesign capacity mechanisms in a way that addresses not just resource adequacy, but values flexibility needs, technology inclusivity, streamlines approval processes, and cross border integration.

Europe's ancillary services market relies on four pan-European platforms under the, each targeting a distinct reserve product to ensure grid stability amidst rising renewables integration. Europe's balancing market now relies on four EU-wide platforms - (i) FCR Cooperation for Frequency Containment Reserve, (ii) PICASSO for automated Frequency Restoration Reserve (aFRR), (iii) Manually Activated Reserves Initiative (MARI) for manual Frequency Restoration Reserve (mFRR), and (iv) Trans-European Replacement Reserves Exchange (TERRE) for Replacement Reserves. Together, they harmonize procurement and cross-border exchange of reserves, streamlining gate closures, auction rules, and settlement (Martins, 2024).

Figure 14: EU's power market operation

FCR Cooperation	PICASSO	MARI	TERRE
[Source –Synertics]	*[Source – Synertics]*	*[Source- Synertics]*	*[Source – Synertics]*

Compensation mechanisms and business models

EU member countries deploy a diverse mix of ESS compensation instruments and business models. including capacity markets, ancillary service revenues, reserve markets.

- Capacity mechanisms: Capacity mechanisms cover 80% of EU (as of 2020) but differ significantly across member countries based on market design (auctions vs strategic reserves), technology eligibility, contract duration, and revenue stacking – illustrated below (Eurelectric, 2025).
    - *Italy's* MACSE competitive auctions/capacity markets offer long-term, technology-neutral contracts, 15 years for BESS and 30 years for pumped hydro, complementing with revenue stacking via ancillary services for long duration ESS (Strategic Energy Europe, 2025). Italy's FER2 decree and its Capacity Market mechanism are designed to support the integration of energy storage, particularly when co-located with renewable energy sources (Lardizabal, 2024).
    - Poland secured BESS total capacity obligations > 8 GW (as of 2025) under auctions (Maisch, M., 2024). Spain is drafting capacity market legislation for ESS, allowing long-duration systems to stack revenues from capacity payments, ancillary services, energy arbitrage, and balancing markets (Energy Box, 2024).
    - France relies on strategic reserves and fixed capacity payments instead of auctions (RTE, 2018).
    - Ireland uses derating factors under Capacity Remuneration Mechanism (CRM)to reward longer-duration BESS with higher capacity payments (SEM Committee, 2022).
- Ancillary Services: Poland launched ancillary service markets in 2024, with BESS returns peaking at EUR 1 million/MW (Gifford, 2025). Belgium's ancillary services market, operated by Elia, allows both standalone and aggregated battery storage to participate in FCR, aFRR, and mFRR services. Similarly, Germany and Nordic countries, enable ESS participation in both the FCR (primary reserve) and aFRR (secondary reserve) through their balancing markets (Castellanos, 2024).
- Wholesale markets: BESS operators leverage wholesale markets in countries like the Germany (EPEX SPOT market), the Nordics (Nord Pool), Italy, Greece to generate merchant revenue through day-ahead and intraday arbitrage.
- Reserve Markets: Finland includes pumped hydro, BESS, and supercapacitors in reserve markets (Lieskoski, Koskinen, Tuuf, & BjörklundSänkiaho, 2024).
- Behind-the-Meter (BTM) Storage: France supports industrial BTM storage via demand response participation and frequency services under the Block Exchange Notification of Demand Response (NEBEF) mechanism (RTE, n.d.); the Netherlands supports

decentralised ESS through net metering regulations and subsidies under the Stimulation of Sustainable Energy Production and Climate Transition (SDE++) Scheme (Interreg NWE., 2022).

- Cross border ancillary services/revenue stacking: ESS can earn revenue through cross border activation of aFRR services via the EU-wide Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation (PICASSO) developed by ENTSO-E. For example, *Belgium* joined PICASSO in 2024, enabling energy storage systems in the country to participate in the European aFRR market and access cross-border balancing opportunities.

Business models

- Co-location models, e.g., *Germany,* under *Innovation Tender Auction*, requires deployment of combined solar PV and storage systems, awarding successful bidders a fixed market premium contract (Norman, 2024).
- Aggregator driven models for pooling ESS, allows smaller storage projects to participate in balancing markets (e.g., aFRR and mFRR) - Germany, Austria, Czech Republic, Netherlands, Belgium, Denmark, Slovakia, Bulgaria, Greece, Lithuania and Finland.
- Merchant storage developers balance between capacity contracts (e.g., Italy) and market-driven revenues from arbitrage and ancillary services.
- Other emerging technologies like flywheels, compressed air energy storage (CAES), rely on pilot tenders, state-aid, and subsidies. For e.g., European Commission approved state-aid for flywheel technology in Italy.
- Virtual Power Plant (VPP) business model is gaining strong traction in countries such as Germany, France, Belgium, Netherlands where liberalized electricity markets and advanced digital infrastructure enable the aggregation of distributed energy resources—like batteries, solar, flexible loads, and EVs—for participation in energy and ancillary service markets.

EU electricity markets are reforming tariff structures and market access rules to value fast-acting flexible resources such as BESS in ancillary services markets, including frequency regulation, balancing, and reserves. Among the available revenue streams, fast frequency regulation is the most accessible, with 19 out of 29 countries (including a few European countries that are not EU members) offering this service. Balancing and restoration services are available in 14 countries, while only eight countries have developed broader ancillary service markets. Only Germany, Portugal, Spain, and the UK offer all 3 main revenue streams. In addition, participation of battery systems in capacity markets – which compensate systems for their availability to support the grid during peak demand periods, even when not dispatched - is permitted in only 7 countries (ees-europe, 2025).

Broadly, European energy storage markets are evolving with harmonized yet flexible regulatory frameworks, while national strategies and market designs continue to shape deployment, compensation mechanisms, and business models.

KEY TAKEWAYS

- **Strong regulatory momentum has positioned storage as a key flexibility asset, with EU-wide reforms like the Clean Energy Package and Electricity Market Design mandating member states to assess flexibility needs. EU defines storage as neither generation nor consumption, enabling revenue stacking through ESS participation in energy, capacity, and balancing markets. Capacity Mechanisms are proving to be a source of reliable revenue stream in the EU, for example, (Italy's long-term capacity contracts via MACSE auctions, Ireland's performance-based capacity payments under CRM, strategic reserves in France, Belgium.**
- **BTM business models, particularly for C&I segment, are gaining traction with policies supporting independent aggregators and VPPs to unlock market revenues.**
- **Cross-border balancing market integration enhances ESS value, as platforms like PICASSO and MARI enable ESS to earn from ancillary services across EU markets. Belgium's participation in PICASSO exemplifies this transnational opportunity.**
- **Targeted support for emerging use cases is extended through EU funding (RRF, TCTF) and national schemes (e.g., France's NEBEF, Netherlands' SDE++) for expanding ESS in islands, remote areas, and BTM industrial settings.**
- **Emerging technologies such as flywheel storage, CAES are supported through pilot tenders, state-aid, subsidies.**
- **EU is a frontrunner in developing Battery Regulation (2023) to enforce circularity.**

CASE STUDY

ELECTRICITY BALANCING GUIDELINE (EB-GL)

EUROPE

EB-GL is a comprehensive regulatory framework established by Commission Regulation (EU) 2017/2195 to integrate and harmonize European electricity balancing markets..

A regulatory framework which stabilizes the internal energy market of the European Union (EU) and balances the grid system by coordinating the procurement of balancing capacity and the activation of balancing energy across Member States.

CURRENT STATUS Operational since 2017

CONTEXT

- The European Commission recognized that a fully functioning and interconnected internal energy market is crucial for security of supply, increasing competitiveness, and ensuring affordable energy prices for all consumers.
- Increasing shares of variable renewable energy highlighted the need for more efficient, fast-acting balancing rules to provide incentives for market participants to solve system scarcities they are responsible for.
- Prior to this regulation, balancing markets were largely fragmented by national borders, leading to inefficiencies and limited cross-border trade of balancing services.
- The objective of EB-GL is to ensure harmonisation of electricity balancing rules and facilitating the exchange of balancing resources between European TSOs.

IMPLEMENTATION

Phased implementation across all EU Member States, with specific conditions for isolated systems and non-EU participation

STAKEHOLDERS

Transmission System Operators (TSOs), Distribution System Operators (DSOs), Regulatory Authorities, ENTSO-E, and Market Participants.

GOVERNANCE

TSOs, Agency for the Cooperation of Energy Regulators (ACER), and ENTSO-E

ACTIVITIES

The implementation of the EB-GL is executed through a series of coordinated technical and operational functions:

- Regulation (EU) 2017/2195 was adopted on 23 November 2017 to move beyond fragmented national arrangements toward harmonized technical, operational, and market rules for electricity balancing, including common principles for procurement and settlement.
- Standardization of Products: TSOs must define and use standard products for balancing energy to facilitate exchange and allow for the creation of common merit order lists and adequate market liquidity.
- European Platforms: Establishes common European platforms for operating the imbalance netting process and enabling the exchange of balancing energy from Frequency Restoration Reserves (FRR) and Replacement Reserves (RR).
- Imbalance Settlement Harmonization: Requires the harmonization of the Imbalance Settlement Period (ISP) to 15 minutes across Europe to support intraday trading and foster consistent delivery windows and trading products.
- Market-Based Procurement and Activation: The guideline sets out rules ensuring the procurement of balancing capacity is fair, objective, transparent, and market-based, utilizing a TSO-TSO model while avoiding undue entry barriers for new entrants like demand-response aggregators.
- Pricing Methodologies: Implements pricing methods for standard balancing products that reflect the real-time value of energy and provide positive incentives for market participants to maintain or restore system balance.

IMPACTS

- The framework facilitates participation and market access by ensuring a fair, transparent, and non-discriminatory approach that enables demand response, aggregation facilities, and energy storage to compete on a level playing field with traditional balancing services.
- It promotes efficient dispatch and system efficiency through the use of self-dispatching or central dispatching models that determine generation and consumption schedules based on integrated scheduling processes.
- Operational security and coordination are maintained by requiring TSOs to coordinate closely with DSOs to manage impacts on their respective systems while ensuring grid stability.
- Standardized qualification processes ensure that all balancing service providers pass a rigorous assessment defined by TSOs in cooperation with DSOs.

- Enhanced competition and market integration increase the liquidity of short-term markets by allowing more cross-border trade and efficient use of the existing grid for balancing.
- The regulation contributes to operational security and long-term development by supporting the efficient operation of the electricity sector while maintaining system frequency within predefined stability ranges.
- Renewable support and integration efforts assist in the achievement of European Union targets for renewable generation by making the grid more resilient and fit for variable supply.
- Consumer benefits and cost savings are realized through a common merit order list model that ensures the most cost-efficient activation of balancing energy bids across the Union, aiming to provide affordable prices through optimal system management.

03

Key Findings from Global Best Practices and the Way Forward for India

The integration of ESS is crucial for facilitating deeper integration of renewables into the power grid by mitigating the intermittent quality of such energy generated from RE sources. Energy storage also improves the reliability, safety and security of electricity grid through enhanced controls of fluctuating voltage and frequency. Based on our review and stocktaking of global best practices from Germany, the U.S., Australia, the UK, Canada, and the EU, several key findings emerge across policy and regulation, market structure and grid operation as well as compensation and business model categories, as outlined below:

POLICY AND REGULATORY FRAMEWORKS

- *Progressive Policy Evolution and Long-Term Strategic Planning:* These countries exhibit a phased approach to policy development, initiating with foundational acts to recognize ESS (Germany's EEG 2015, UK's early R&D funding and Renewable Energy Roadmap) and progressing to comprehensive, forward-looking strategies (US's Energy Storage Grand Challenge 2020, Australia's National Battery Strategy 2024, UK's Clean Power Action Plan 2030). These strategic plans provide clear targets and investment signals. The EU's revised TEN-E Regulation enables EU funding through PCIs, supports cross-border projects, and streamlines permitting while the EU's Electricity Market Design (EMD) emphasises 2-way CfD for ESS revenue certainty.

- Formal Classification and Legal Recognition: Definitive classification of ESS within energy legislation is paramount for market clarity and operational efficacy. Examples include Germany's Energy Industry Act (EnWG) classifying large-scale ESS as controllable consumption equipment, and the UK's Energy Act 2023 formally defining electricity storage as a subset of generation. This formal recognition addresses critical regulatory ambiguities, such as enabling grid feed-in exemptions and eliminating "double charging" on electricity duties or consumption levies. The 2019 EU Electricity Directive formally defines energy storage as a distinct activity in the power system, enabling third-party ownership and market participation.

- Targeted Financial Incentives and Innovation Support: Governments employ a diverse array of financial mechanisms to de-risk investment and spur innovation. These include capital subsidies for residential installations (e.g. Germany's KfW 275 Program), refundable tax credits for stationary ESS (Canada's Clean Technology Investment Tax Credit) investment tax credits for standalone storage (US's Inflation Reduction Act), concessional finance for grid-scale projects (Australia's CEFC Investment), and competitive funding for advanced technologies (Australia's ARENA's Advancing Renewables Program). Furthermore, innovation auctions (Germany's RES Act) and R&D pathways for long-duration technologies (US's Storage Innovations 2030, Horizon Europe), grants including for cross border ESS (Connecting Europe Facility) are crucial for technology maturation.

- Streamlined Grid Connection and Interoperability Guidelines: Regulations focused on simplifying grid connection procedures and establishing clear technical and operational criteria are vital. This encompasses grid connection ordinances (Germany's KraftNAV), and detailed technical guidelines for integration (Australia's AEMO's Storage Integration Guideline), facilitating a faster and more predictable pathway for ESS projects.

- Mandates for Wholesale Market Integration and Aggregation of DERs: Regulatory bodies explicitly mandate the integration of energy storage resources into wholesale markets (US's FERC Order No. 841) and enable the aggregation of distributed energy resources (DERs) to participate in these markets (US's FERC Order No. 2222, Ontario (Canada) IESO Market Renewal and DER Roadmap). This fosters competition, unlocks new business models like Virtual Power Plants, and promotes a decentralized energy ecosystem.

- Environmental Compliance and Circular Economy Principles: Policies addressing the entire lifecycle of batteries (EU Batteries Regulation 2023), such as Extended Producer Responsibility (EPR) mandates for battery collection, recycling, and safe disposal (Germany's German Battery Act, US's Battery and Critical Mineral Recycling Act), are fundamental for promoting sustainability and circularity in ESS deployment.

- Addressing Local Grid Contribution Disparities: Exemptions from double network charges (EU Electricity Regulation 2019), exemptions from financial contributions toward grid infrastructure development for small-scale ESS (Germany's BKZ exemption for systems up to 30 kW) directly benefit residential and community-scale deployments, reducing barriers to localized integration.

MARKET STRUCTURE AND GRID OPERATION

- *Liberalized and Unbundled Market Architecture:* All leading countries operate with unbundled, liberalized electricity market structures where generation, transmission, distribution, and retail functions are distinct. This framework allows for competitive participation of ESS alongside traditional generation and flexibility providers.

- *Decentralized Regulatory Authority with Centralized Market Coordination:* The US model exemplifies a decentralized regulatory structure where the Federal Energy Regulatory Commission (FERC) governs interstate electricity markets, while individual states retain authority over distribution and retail operations. Within this, regional wholesale markets are managed by RTOs/ISOs, responsible for procuring market products. This hybrid structure allows for tailored market designs within a broader federal framework. Canada's approach similarly combines strong federal-level investment signals (Clean Tech ITC, SREPs) with provincial autonomy in designing and implementing targets, market rules, and procurement pathways. In the EU, national energy regulators operate under a decentralized structure, while cross-border coordination is facilitated through EU-wide market platforms and regulatory alignment.

- Multi-Product Market Participation for ESS: ESS are actively integrated into various market products, including day-ahead and real-time energy markets, capacity markets, and a comprehensive suite of ancillary services crucial for grid stability, including frequency containment reserve, automatic and manual frequency restoration reserves, operating reserves (spinning and non-spinning), and fast frequency response services (Germany's defined FCR, aFRR, mFRR; Australia's FCAS reform and FFR introduction; UK's Dynamic Containment). This maximizes the value proposition of ESS. Canada's grid-scale ESS projects benefit from revenue stacking across capacity, energy, and ancillary services, while EU cross-border platforms like PICASSO and MARI enhance ESS access to ancillary services markets.

- Performance-Based Market Participation and Transparency: ESS are actively integrated into these markets, either directly or through aggregators, participating in energy, capacity, and ancillary services. Market participation is governed by mandated performance standards, stringent testing protocols, and requirements for data transparency (Germany's BNetzA regulations & Canada's IESO procurements). This ensures the reliability and accountability of ESS assets providing grid services. The EU emphasizes aggregator accountability and transparent market operations, enabling storage to reliably deliver contracted services.

- Defined Roles for System and Distribution Operators without Asset Ownership: While TSOs manage overall manage real-time system balancing and procure ancillary services, DSOs are increasingly empowered in unbundled markets to procure location-specific flexibility services to manage local constraints via competitive auctions and defer infrastructure upgrades, rather than owning storage assets themselves (UK's DNOs procuring flexibility via auctions).In Canada, Ontario's DER Roadmap and Alberta's evolving distribution regulations support DSO-led flexibility procurement without granting asset ownership. In the EU, storage is classified as a market-based asset, and regulatory frameworks prevent DSOs from directly owning or operating ESS, instead promoting third-party provision through competitive means.

- Market Mechanisms for Grid Congestion Management: Regulatory frameworks explicitly mandate the use of flexible resources, including ESS, to alleviate grid congestion and prevent network overloads (Germany's Redispatch 2.0 under NABEG). This strengthens the role of storage as a non-generation asset in system operations. In Canada, Ontario pilots' non-wires alternatives using ESS, supported by federal programs like SREPs in remote and Indigenous communities. In the EU, storage addresses network constraints with national schemes and EU funds (RRF, TCTF) targeting islanded, remote, and BTM industrial use cases.

COMPENSATION MECHANISMS AND BUSINESS MODELS

- *Diverse Revenue Streams for Value Stacking:* ESS compensation models support revenue stacking by allowing participation in multiple market segments, enabling access to diverse revenue streams that enhance economic viability. These include payments for Frequency Containment Reserve (Germany's FCR payments), energy arbitrage (buying low, selling high in wholesale markets), and capacity payments through competitive auctions (UK's Capacity Market), Ontario's Capacity Auction, and Alberta's merchant market (Canada), as well as co-located renewables plus storage revenue streams in Germany, Canada, and the Netherlands (EU).

- Reliability-Based Payments and Obligations: Mechanisms are in place to ensure system reliability by incentivizing firm capacity, including ESS. The Retailer Reliability Obligation (Australia's RRO) encourages retailers to contract or invest in firm resources to meet peak demand and reliability targets. Similar mechanisms are seen in Ontario's Resource Adequacy Framework (Canada) and capacity remuneration mechanisms in Italy and France (EU), where ESS competes as firm, dispatchable capacity.

- Long-Term Revenue Certainty for LDES: Emerging practices provide mechanisms for long-duration energy storage to ensure revenue stability, such as minimum fixed price guarantees (Australia's NSW Long-Term Energy Service Agreements) or Cap-and-Floor regimes (UK's proposed Cap-and-Floor for LDES). These address the higher upfront costs and longer payback periods of LDES technologies. In Canada, federal programs such as Clean Tech ITC and SREPs are combined with provincial tenders (e.g., Ontario) and regulatory frameworks (e.g., Alberta's AESO market access reforms) to de-risk storage investment. In the EU, mechanisms like Italy's long-term contracts, and France's strategic reserves are enabling bankable revenue streams for LDES technologies.

- Compensation for Rapid Grid Stability Services: Specific market products and compensation mechanisms are introduced to reward the fast response capabilities of ESS. Examples include enhanced frequency response auctions (UK's EFR auction), Fast Frequency Response (FFR) services (Australia's FFR MAS rule), and dynamic containment services (UK's Dynamic Containment), and participation of ESS in fast reserve and frequency response through TSO's balancing services (France's FCR and aFRR markets). In the EU, ESS earns from ancillary services across borders through platforms like PICASSO and MARI. Canada's energy and ancillary service markets allow revenue stacking and operational flexibility at grid scale.

- Payments for Network Support and value for Demand-Side Flexibility: ESS are compensated for providing network support services to defer infrastructure upgrades or manage localized congestion, typically through contracts with distribution or transmission operators. Additionally, compensation is available for demand-side flexibility, allowing storage operators to offer services into wholesale markets by responding to system stress periods (Australia's Wholesale Demand Response Mechanism). In Canada, Ontario is actively piloting non-wires alternatives using ESS for congestion relief, and in the EU, DSOs and TSOs procure local flexibility to manage constraints, with support from EU funds such as RRF and TCTF.

- Avoided Charges and Tax Exemptions: Policies granting exemptions from grid usage charges and electricity duties for stored electricity when reinjected into the grid significantly improve the financial viability of grid-scale ESS (Germany's Electricity Duty Act exemption, UK's exemption from final consumption levies). This addresses the "double charging" issue. Canada's BTM storage in Alberta and Ontario is used to manage Global Adjustment charges and time-of-use pricing, while the EU's Electricity Market Directive \prevents double charging, enabling better market access for storage

Business models for ESS: ESS business models have evolved across diverse deployment structures to maximize revenue streams and optimize grid integration. Some of the commonly adopted business models in these countries are:

- *Independent Project Developers (Merchant Storage)* operate ESS as standalone projects focused on revenue generation through energy arbitrage and ancillary service market participation.

- Utility-Owned Models under Regulated Frameworks integrate ESS within grid infrastructure under Regulated Asset Base (RAB) mechanisms, targeting grid resilience and investment deferral.

- Aggregator-Led Virtual Power Plants (VPPs) pool distributed ESS units to enable market participation for behind-the-meter assets across energy, capacity, and ancillary services.

- Hybrid Renewable Energy-Storage Projects co-locate ESS with solar or wind assets to enhance dispatchability, enable energy smoothing, and access feed-in and ancillary markets.

- Value Stacking and Optimization Services represent sophisticated models leveraging multiple concurrent revenue streams—such as capacity payments, wholesale arbitrage, and local grid services—often supported by optimizers and trading partners, with TSOs/DSOs engaging ESS for localized network support without direct ownership.

INDIA'S ENERGY STORAGE EVOLUTION

India has achieved great progress toward energy transformation with a multifaceted, multisectoral strategy since the Paris Agreement in 2015. India's energy mix is moving away from fossil fuels and toward renewable energy. The fluctuation associated with renewable energy causes challenges such as grid balance, necessitating need for flexibility. ESS generation fluctuation in renewable energy sources, enhances grid stability, allows energy/ peak shifting, offers ancillary support services, and enables greater integration of renewable energy. By minimizing peak deficits, peak tariffs, carbon emissions, deferred transmission and distribution capital expenditures, and reducing energy arbitrage, storage systems will also benefit consumers.

According to CEA's NEP 2023, solar and wind power capacity are expected to reach around 365 GW and 122 GW, respectively, by 2031-32, and energy storage demand is expected to be 73.93 GW (26.69 GW from PSP and 47.24 GW from BESS), with a storage capacity of 411.4 GWh (175.18 GWh from PSP and 236.22 GWh from BESS). The Electricity (Amendment) Rules, 2022, regarded Energy Storage Systems as a component of the power system that can be utilized independently or in conjunction with generating, transmission, and distribution infrastructure, with status based on its application.

In August 2023, the Ministry of Power unveiled the "National Framework for Promoting Energy Storage Systems" to facilitate the country's energy transition. The Viability Gap Funding (VGF) program, which was launched in October 2024, aims to expedite BESS implementation in order to improve grid stability and integrate more renewable energy. The Central Government will provide a VGF of up to 30% of the BESS capital cost or Rs.27 lakh per MWh, whichever is lower.

The CEA's recommendation to include a minimum 2-hour co-located ESS, equivalent to 10% of the installed solar capacity, in future solar tenders would increase supply reliability at the consumer level and protect distribution licensees from over-injection during solar hours. With an investment of Rs. 18,100 crore, the PLI-based National Programme on Advanced Chemistry Cell (ACC) Battery Storage plans to establish an aggregate ACC production capacity of 50 GWh for ACCs and an additional cumulative capacity of 5 GWh for Niche ACC Technologies (MNRE, 2025). In an effort to increase domestic manufacturing capacity, RIL was granted 10 GWh ACC capacity under the PLI scheme in the most recent bidding.

Though India's policy and regulatory ecosystem for ESS is still maturing, there remains significant scope for further improvement when juxtaposed with global best practices. Here are a few aspects that require greater attention:

- Central and State-Wide Policy Alignment: There is a critical need for States to make commensurate Policies & Regulations with those at the Transmission level, made at Central Govt. Level i.e by MOP, CEA &

CERC. While positive facilitations have been made at the Transmission level to expand the electricity market and encourage Storage, many States are yet to align, which is crucial for overall improvement, particularly at the distribution level. Taking the U.S. case as an example, energy storage market operates through a dual regulatory framework where FERC governs wholesale market participation via ISOs/RTOs (enabled by Orders 841 and 2222), while State PUCs regulate storage deployment, interconnection, and retail tariff structures. In order to enable complete value stacking for storage at both the transmission and distribution levels, the FERC and state PUCs are successfully coordinating.

- Time of the Day (ToD) Tariff as an Enabler: For storage at the distribution level to be viable, the first enabler is ToD Tariff, requiring a sufficient gap between peak and non-peak energy prices. The current uniform price of bulk power throughout the day, without providing signals to peak or off-peak load conditions, renders storage unviable independently. Whereas in Canada, the BTM storage compensation largely leverages time-of-use (TOU) pricing structures in provinces like Ontario, British Columbia, and Quebec. This approach incentivizes customers to shift energy consumption away from peak periods, which helps reduce their electricity bills, enhances grid stability, and can even defer expensive infrastructure upgrades.

- Capacity Market and Resource Adequacy: Introduction of a Capacity Market at the earliest is essential to facilitate Discoms in managing various needs of Resource Adequacy. This includes ensuring capacity tie-up with adequate base load, peaking generation resources, requisite ramping capabilities (both upwards & downwards), and Storage, addressing specific requirements of BESS at both Transmission and Distribution levels. For instance, the UK's Capacity Market provides long-term contracts (up to 15 years for new builds) to ESS, ensuring revenue stability and incentivizing investment for grid resilience. Similarly, Australia's Retailer Reliability Obligation (RRO) encourages retailers to invest in firm capacity, including storage, to meet peak demand and reliability targets.

- Institutionalizing DSO and Aggregators: The institutionalisation of DSOs become inevitable with increased penetration and participation of distributed BESS. Furthermore, the enablement of regulations for aggregators at the State level will revolutionise distribution operation, facilitating peer-to-peer energy trading, aggregation of many BESS, and bidding in Ancillary services. For example, Germany's Electricity Market Act explicitly allows TSOs to manage ancillary services, with energy storage participating directly or via aggregators. Similarly, FERC Order No. 2222 in the US enables the aggregation of DERs, including BTM storage, to participate in wholesale markets, unlocking new business models like VPPs. While this transition is a regulatory priority, embedded flexibility resources remain underutilized due to the disaggregated nature of DERs, inadequate Information and Communications Technology (ICT) infrastructure, and the absence of an active network operator. Addressing this requires empowering the DSO to procure these storage-backed services through transparent, competitive mechanisms. Consequently, regulators must modify existing codes covering scheduling, despatch, integrated network planning, and resource adequacy to formally integrate BESS as operational assets (Abhyankar, 2023).

- Deep vs Shallow Markets: India's electricity market remains relatively shallow, with only around 7% of total consumption transacted through power exchanges – significantly lower than global benchmarks, where liberalized, market-based mechanisms form the backbone of electricity trading (Michael, 2024). The dominance of long-term power purchase agreements, coupled with regulatory constraints and limited participation from DISCOMs, has impeded the development of a competitive, transparent, and dynamic market ecosystem. To enable efficient price discovery and resource optimization, India must gradually transition toward a "deep market" structure, as seen in these countries, where real-time trading, ancillary service markets, and demand-side participation are integral components.

Global best practices – such as liberalized energy markets, structured ancillary services, incentive-aligned procurement models, and VPP-based aggregation – offer actionable pathways to address these systemic gaps. As India's grid evolves and modernizes, aligning with such frameworks will be crucial to unlocking the full value of distributed ESS, thereby ensuring technical efficacy, institutional viability, and economic scalability.

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