PAN AMERICAN FINANCE

Global Energy Storage Market Review

2022

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Contents

1. EXECUTIVE SUMMARY

Executive Summary

Transition Towards Decentralized Grid Framework

Network operators are increasingly looking for flexible power system capabilities to support renewable energy's estimated 90% share of total output by 2050. The relative techno-economic qualities and local grid restrictions will determine the optimal combination of flexible resources. Importantly, traditional grid management approaches rapidly give way to alternatives employing a decentralized grid structure. The new approach emphasizes energy storage resources.

Energy storage resources, such as pumped hydropower and batteries, provide a competitive grid management alternative when paired with combined cycle gas turbine facilities or demand response.

Transition to Energy Storage is Subject to the Level of Policy / Regulatory Support

Lithium-ion has emerged as the leading technology choice in the installed battery storage capacity of 27GW by the end of 2021, owing to commercialization and economies of scale. Between 2018 and 2021, battery-based storage more than tripled. However, due to the market's lagging regulatory stance, sustained growth in this segment is yet to be achieved.

More than two-thirds of battery storage capacity comes from the utility-scale segment, which serves the power transmission industry. This is the most essential deployment position for battery storage as utilities and transmission operators negotiate the energy transition in their operations.

Batteries are Assuming Active Roles in the Grids

As networks handle significant differentials in peak and off-peak energy pricing (often reflecting an influx of intermittent energy), energy arbitrage is becoming the most common deployment for batteries. Overall, frequency management as part of grid ancillary services is the operator's most preferred application for battery storage. Frequency regulation is fairly saturated in some developed markets, such as the United States and the United Kingdom. In emerging markets, evolving regulations could begin with this segment before moving on to others.

All the same, the market outlook is that of a five-fold rise in battery storage capacity by 2030. Grid-scale units, especially those led by co-located battery storage with renewable generation, is the major growth driver. Lithium-Ion continues to be in market leadership position even as other technology options enter the fray in a gradual rollout.

Long Duration Energy Storage ("LDES") Gaining Maximum Attention

With increasing complexity and imbalances on the horizon, long-duration energy storage (LDES) is receiving the most attention from operators and regulators alike. However, battery-powered LDES has yet to be proven in terms of technology maturity or economics.

Investor focus has risen sharply on this part, as commercialization could make rapid dent in the global storage market and the power system at large. There are about 7-8 leading LDES battery technologies in contention for commercialization. This includes major technologies such as thermal storage (molten salt), compressed air, iron-air and sodium-ion where feasibility tests and demonstration projects are underway.

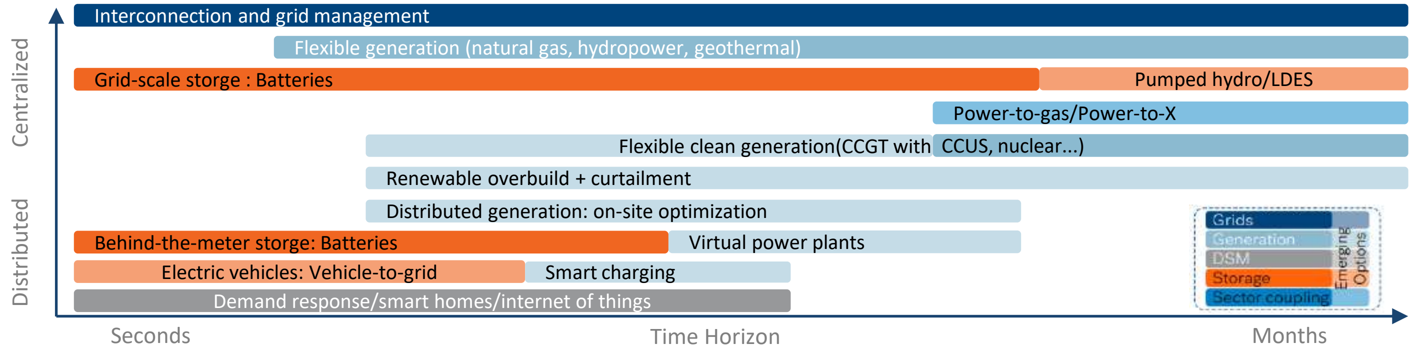
2. FLEXIBLE GENERATION

Flexible Generation

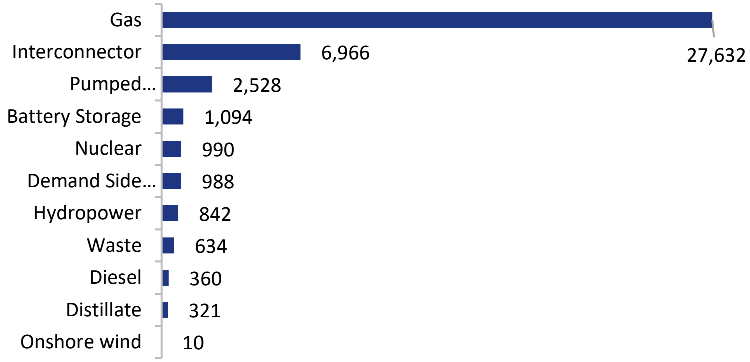
The Case for Flexible Generation

- Rising renewable/intermittent energy generation and carbon emission policy targets point to a change in the standard processes of power market transactions and network reliability, where flexible generation assets have a critical role
- There is a matrix of flexible generation systems positioned by their respective roles in the grid functioning. Batteries are gradually displacing gas-based plants from having an outsized role in capacity planning in several wholesale markets (such as in the US) due to the commercials
- The flexible generation capacity options for grid operators continues to be a mix of the new and old generation technologies

Tentative Positioning of Flexible Power Generation Systems



Capacity Awarded in UK's Four Year Ahead Capacity Auction of 2021 (MW)



Source: National Grid Electricity System Operator
Notes: Data refers to the four year ahead capacity market auction results published as of February 2022

- UK's recently awarded capacities in the four-year ahead (T-4) capacity auctions show gas-based plants corner nearly two-thirds of the total
- Pumped hydro and batteries find a position below that of interconnectors. All generation capacities in such markets are subject to de-rating – a wind farm has a larger de-rating than a combined cycle gas turbine
- Progressively, the transition of the existing centralized grid structure to a decentralized one is central to the future flexibility in power generation and overall systems
- The advent of Virtual Power Plants (VPPs) has been gradually rising in the European market. For instance, as of April 2022, Germany's Next Kraftwerke held a 10GW worth of total networked VPP capacity

3. ENERGY STORAGE IN A FLEX ENVIRONMENT

Energy Storage in a Flex Environment (1/2)

Introduction

- The narrative for energy storage and flexibility is limited to the power transmission system’s reliability and balance. The rise in intermittent or non-dispatchable power generation (contrasting the predictable baseload) and the significant role of distributed energy resources (against a predominant centralized power earlier) gradually upended the standard grid management practices
- Many of the gaps in meeting flexibility requirements are filled by commercially deployed storage systems such as pumped hydropower and batteries. A sharp decline in the cost of Lithium-Ion, fast-ramping batteries have progressively displaced gas-based peaking plants in most of the developed markets. Among the storage technologies with commercial deployment at scale, the near to medium-term visibility is the strongest for the Lithium-Ion battery units
- The hydroelectric generation legacy base remains an essential resource for power system flexibility. Recently, hydropower facilities, particularly reservoir-based plants, have found a renewed currency for their capabilities in managing variable demand, intermittency, and ensuring an emission-free footprint. Pumped hydropower capacity meets more than 90% of bulk storage needs in the United States (the world's largest energy storage market)
- Demand for 4+ hours’ storage segment paving the way for Long Duration Energy Storage (LDES) to moderate the gross and net peak demand. Competitive technologies that can be provisioned for multiple hours, days, or weeks to support system exigencies are in high demand
- Even though commercial scale is still some time away, investor interest in LDES is understandably high (3.5 times increase in global deals between 2018 and 2021)

Existing and Emerging Flexibility Solutions for Different Flexibility Duration Needs

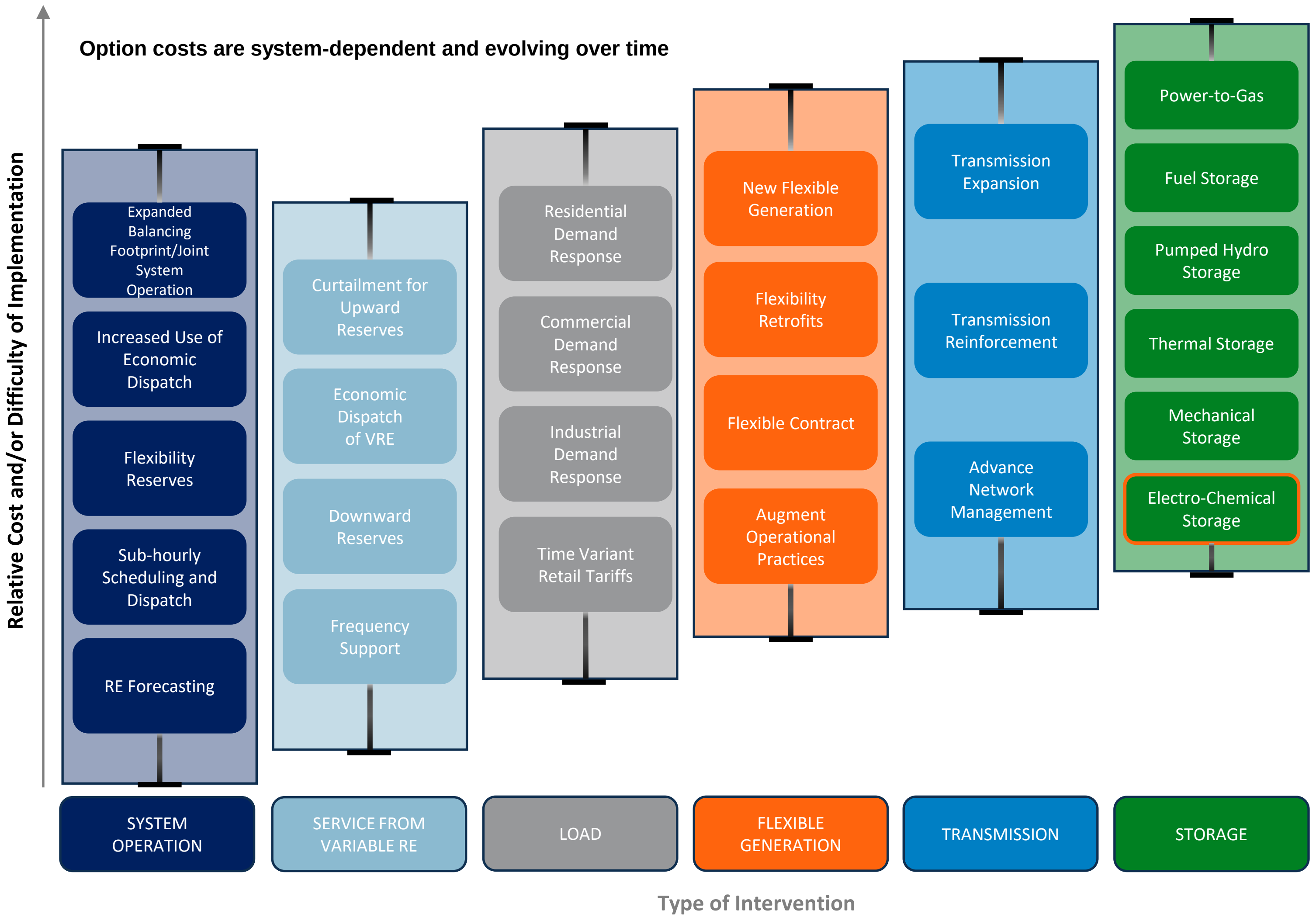
Flexibility Duration	Power System Challenge	Dispatchable Generation	Grid Reinforcement	Curtailment or Feed-in Management	Li-ion Batteries	LDES	Demand-side Response
Intraday	Intermittent Daily Generation	✓		✓	✓	✓	✓
	Reduced Grid Stability	✓			✓	✓	✓ (partial)
Multi-day, Multi-week	Multi-day Imbalances	✓	✓ (partial)	✓ (partial)	✓ (partial)	✓	
	Grid Congestion	✓ (partial)	✓	✓	✓ (partial)	✓	
Seasonal Duration	Seasonal Imbalances	✓	✓			✓	
	Extreme Weather Events	✓				✓	

Note: LDES refers to Long Duration Energy Storage
Source: McKinsey

✓ Solution ✓ (partial) Partial Solution

Energy Storage in a Flex Environment (2/2)

The Flexibility Supply Curve



Source: National Renewable Energy Laboratory (report on 'Energy Storage Futures')

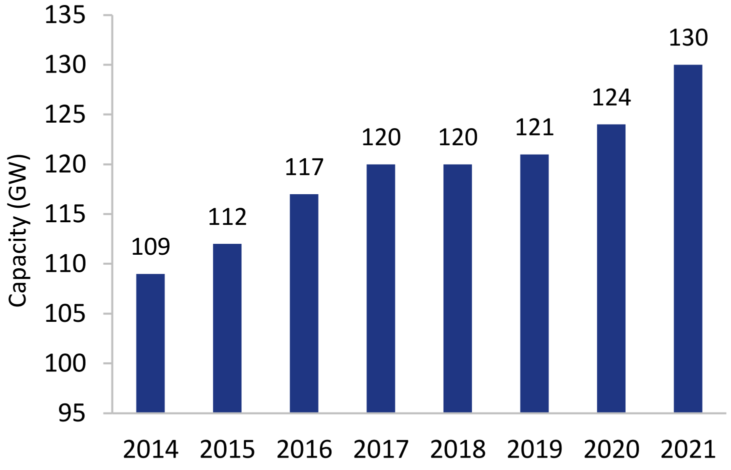
4. GLOBAL ENERGY STORAGE CAPACITY

Global Energy Storage Capacity (1/2)

Introduction

- The purview of energy storage technologies has expanded much beyond the traditional integration requirements associated with renewable energy generation or other forms of decentralized energy resources
- Grid-scale storage is progressively assuming a position in the energy mix, as part of the emerging paradigm of power systems based on flexible generation resources. Grid-scale batteries hold the key to capacity growth. Such battery units are critical in the grid management functions and have capabilities to fulfill multiple roles for network operators if the appropriate incentives are available
- With favourable regulatory factors (power market norms) and technological economies of scale (mainly Lithium-Ion so far), storage industry growth has accelerated in the majority of mature and large-sized energy markets
- Much of the capacity expansion may be attributed to a demand-pull (such as incentives in the bulk power market or tax benefits for storage hybrids) of the global energy sector's emerging transitional phase
- The net balance of costs progressively favour the side of battery storage technologies. Led by Lithium-Ion, majority of the installed capacity base caters to a storage demand of up to 4 hours or below. Lithium-Ion, as a battery technology configuration, has had the benefit of commercialization and economies of scale

Global Pumped Storage Hydropower Capacity

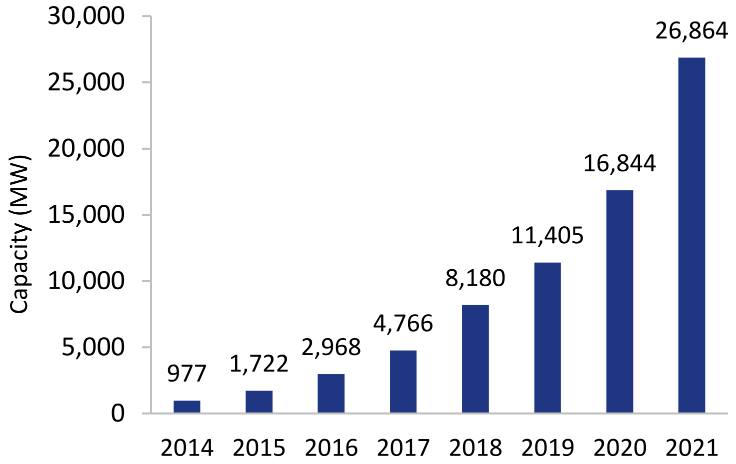


Source: IRENA

- Pumped storage hydropower is a legacy technology that still accounts for more than four-fifths of global energy storage capacity
- Since 2020, there has been an increase in the Pumped hydroelectric storage capacity globally, which corresponds to the rapid rise in renewable energy penetration in the major storage markets (US and China, among others)
- In April 2022, the world's largest pumped storage hydro plant (3.6GW) was commissioned in China
- More such capacities are in fray because of the competitive costs offered by such technologies in the event of rising demand for clean and flexible energy generation

Global Energy Storage Capacity (2/2)

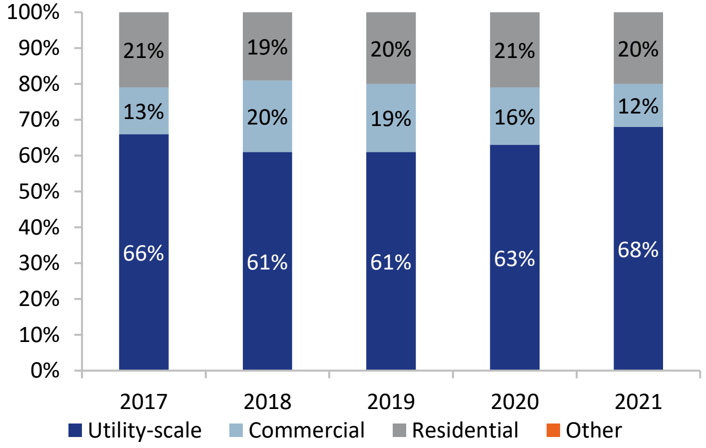
Cumulative Installed Battery Storage Capacity



Source: BNEF

- The trend in capacity deployment by major segments indicates that grid-scale batteries will continue to be important
- The growth achieved so far has been relatively muted, given that many countries have yet to draught relevant regulations
- The majority of battery deployments by utilities have been for frequency regulation. The emerging and popular demand, however, is energy arbitrage, in which battery units serve the power market for the difference in peak and off-peak energy demand

Share of Broad Segments of Installed Storage Capacity



Note: The above chart has 'others' category for 2020 and 2021, at negligible 0.2% and 0.3% respectively, Source: BNEF

- In the current market scenario, residential and commercial storage segments are relatively undervalued. This is because growth in these segments, particularly residential, has been limited to specific demand pockets
- Europe as a region is characterized by the leading role of residential energy storage. This is gradually increasing, not only from grid-connected units, but also from off-grid or behind-the-meter units

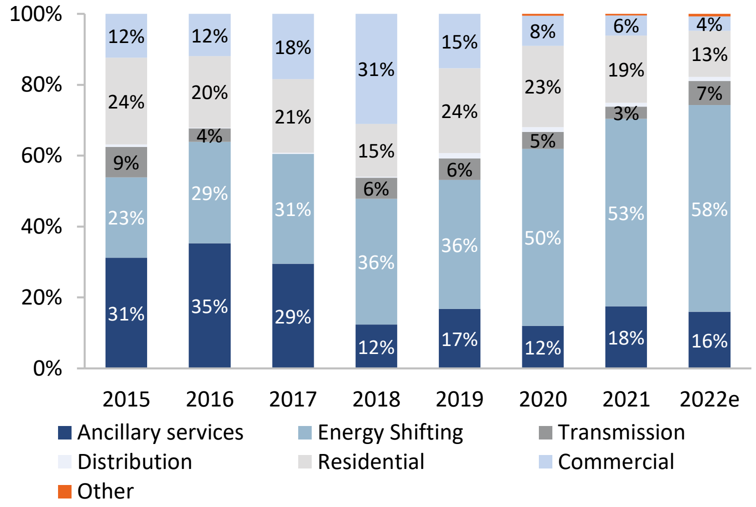
5. STORAGE CAPACITY BY APPLICATION

Storage Capacity by Application (1/3)

Introduction

- Energy storage applications are gradually evolving in contribution, as technologies improve (such as in improved duration), capital costs rationalize, and renewable energy penetration rises in the power mix
- Regulatory changes are gradually enabling a fair share of battery storage units in the overall power market transactions
- Developers and the investor response is proportionate to the visible incentives and returns. The largest markets of the US and China continue to show most of the evidence on progress. Europe, meanwhile, appears to be catching on with gradual regulatory measures
- Frequency regulation has been an important application (among other grid ancillary services) in majority of the energy storage markets. For most of the storage developers, frequency regulation is the most common revenue stack category

Trend in Share of Grid-Scale Battery Storage by Applications

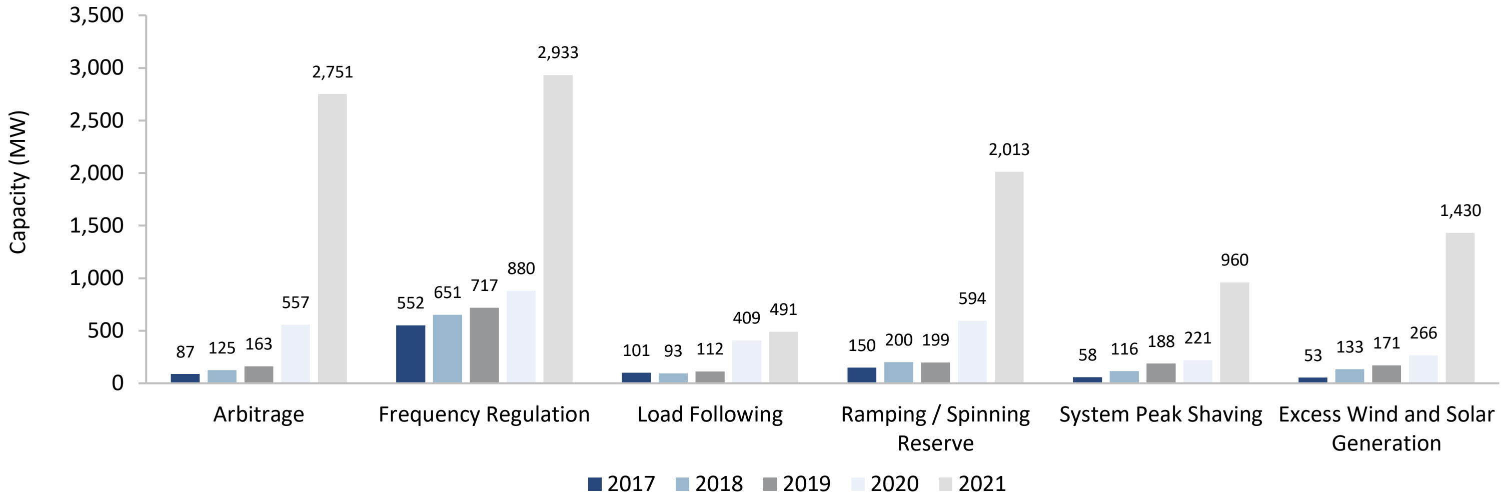


Source: BNEF

- Batteries are well suited in grid stability role because of inherent advantages such as near-instantaneous response to power surges (there is no startup time)
- In the United States, the share of operational battery storage facilities devoted to frequency regulation stood at 60% by the end of 2021
- The UK's energy storage market launched an auction for a new frequency regulation service, namely Dynamic Regulation, by the National Grid in April 2022

Storage Capacity by Application (2/3)

Trend in Battery Storage Application in the US Grid

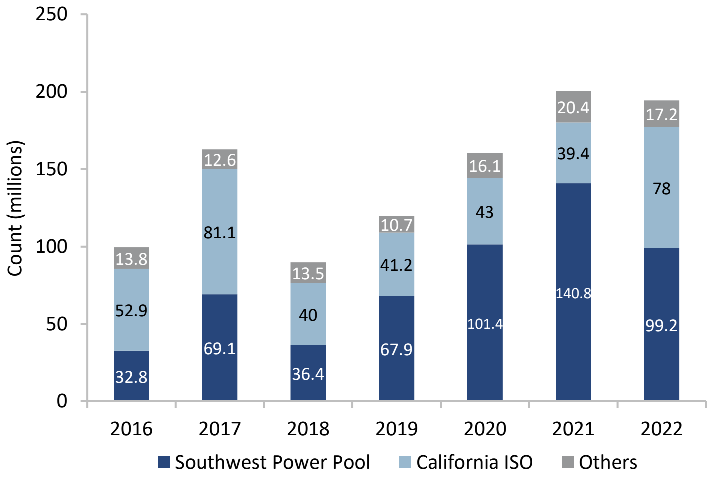


Source: BNEF

- While frequency regulation remains the mainstay among the list of applications, the trend in the major energy storage markets such as the US and UK indicates that it may be nearing saturation levels
- A US Energy Information Administration survey confirmed a disproportionate increase in battery storage deployment for price arbitrage during 2017-21. Rising renewable energy penetration has been a significant contributor to this emerging trend
- A rise in renewable energy power injection in the grid changes the usual shape of day-ahead grid price trend curve. Typically, it leads to lower daytime prices. Battery storage systems are better placed to capitalize upon the spread – charging during the low-price daytime hours and discharging during the higher-price time slots
- It is observed that batteries are progressively filling in the category of spinning reserves that help the operators ensure managing load fluctuations. Here batteries are taking the place of gas-based peaking generation capacities which become unsuitable due to emission norms imposed by regulators
- The factor of emissions has also played a role in grid operators' capacity market auctions (generation capacities reserved for contingency or peak stress). The European electricity market's capacity market is an example in point that disincentivizes fossil fuel-based capacities through cap on emissions

Storage Capacity by Application (3/3)

Number of Times When 5-minute Prices on the US Grid Turned Negative



Note: Data for 2022 is till August 15th.
Source: Bloomberg News (attributed to Yes Energy)

- As grid infrastructure lags new wind and solar generation, batteries may be the only intermediate option
- During 2021, the US grid wholesale prices (5-minute intervals) turned negative about 200 million times across the seven transmission interconnection regions
- Frequency distribution of negative prices was observed to be the highest since 2016, and by 2022 end it could be even higher
- It can be inferred that the primary application of battery storage units will be capacity deferral, in addition to the other roles of grid management

Select Examples of Battery Storage as Transmission Projects

Country	Project	Description
Germany	Netzbooster project	The TSO TransnetBW GmbH has engaged independent third-party battery storage developers for 250MW capacity unit, regarded as the world's largest storage-as-transmission project.
US	National Grid Nantucket project	The transmission utility installed a 6MW battery for better supply reliability during summer season demand, and in the process, defer the need for underwater transmission cable to the island region.
	Oakland Clean Energy Initiative	The utility PG&E led the deployment of 43MW worth of battery storage as an alternative to the conventional transmission connectivity, as the region considered switching over to clean energy sources.
Chile	National Transmission Expansion Plan	The Independent Power Producer AES Gener undertook implementation of two 200MW battery storage projects meant to act as virtual transmission capacities to relieve network congestion.

Source: Energy Storage Association, Fluence Energy press release

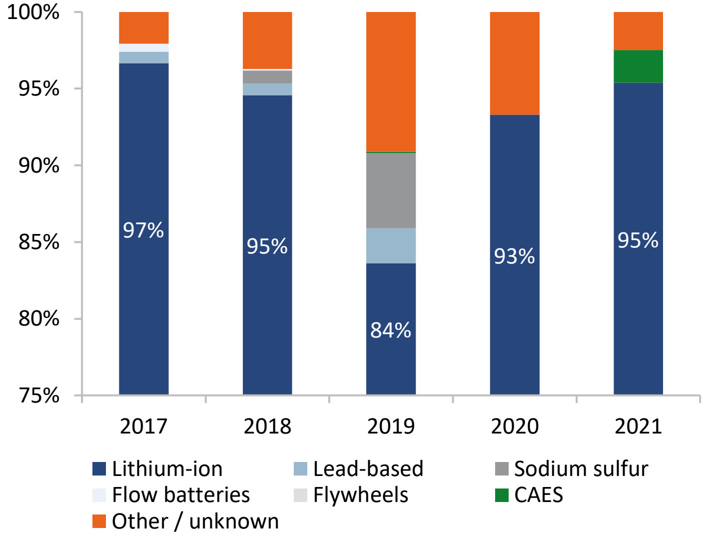
6. STORAGE MARKET BY TECHNOLOGY

Storage Market by Technology (1/2)

Introduction

- Pumped hydropower generation is the conventional, legacy storage technology that is ideally suited best for grid management and its related segments
- Global installed energy storage capacity is still skewed (about 83% share by 2021) in favour of the pumped hydropower stations. However, long gestation periods, complex and lengthy environmental clearances, and sensitivity to locations are the key points of disadvantages that progressively deterred investors from pumped hydropower plants
- Battery manufacturing and its related ecosystem are propelled by the twin forces of grid-scale storage and automotive powertrain, the latter being the more significant one in demand-pull
- As supply reliability and stability become a challenge in the energy mix, LDES is becoming an emerging priority area for both regulators and network operators

Trend in the Technology Mix of Commissioned Battery Storage Capacity



Source: BNEF

- Commercialization and economies of scale in select major technologies such as Lithium-Ion, making it a competitive choice for most developers
- Sodium-ion batteries have recently gained popularity because raw materials are more easily obtained, and the technology is less expensive than Lithium-Ion
- Iron-based batteries are another emerging storage technology that developers are evaluating for standalone grid-scale deployment. Because of the low cost of the raw material (iron), the batteries promise to be far less expensive than other options in the market
- Other technologies, such as thermal storage (based on molten salt) and compressed air energy storage (CAES), are in the pilot or demonstration phase

Storage Market by Technology (2/2)

Performance Characteristics of Energy Storage Technologies

	Lead-Acid	Li-Ion	NaS	Flow batteries	Flywheel	CAES	PHS
Round-trip energy efficiency (DC-DC)	70-85%	85-95%	70-80%	60-75%	60-80%	50-65%	70-80%
Discharge duration (Hours)	2 - 6	0.25 - 4+	6 - 8	4 - 12	0.25 - 4	4 - 10	6 - 20
C Rate	C/6 to C/2	C/6 to 4C	C/8 to C/6	C/12 to C/4	C/4 to 4C	N/A	N/A
Cost in full discharge	$100 - 300/kWh	Early to Moderate	$400 - 600/kWh	$400 - 1,000/kWh	$1,000 - 4,000/kWh	>$150/kWh	$50 - 150/kWh
Development time	0.5 - 1 year	0.5 - 1 year	0.5 - 1 year	0.5 - 1 year	1 -2 years	3 -10 years	5 - 15 years
Operating cost	High	Low	Moderate	Moderate	Low	High	Low
Cycle life	500 - 2,000	200 - 10,000+	3,000 - 5,000	5,000 - 8,000+	100,000	10,000+	10,000+
Maturity level	Mature	Commercial	Commercial	Early to Moderate	Early to Moderate	Moderate	Mature

Source: India Smart Grid Forum (Energy Storage Roadmap)

Comparative Illustration of Battery Storage Assets vis-à-vis Others in Power Supply Security/Reliability

	Nuclear		Storage		Interconnector	Synchronous condensers	Unabated thermal gas	
	Conventional	SMR	Short duration (0.5 - 4 hr)	Long duration (>4hr)	EU-wide	Rotating stabilizers	CCGT/CHP	Peaker
Commercial Readiness	Mature	Nascent	Mature	Intermediate	Mature	Nascent	Mature	Mature
Asset Availability*	81%	Unknown	12-74%	95%	49-90%	No active power	90%	95%
Startup time	12hr>	30-60 min	<0.1 min	0.1 - 10 min	<30 min	N/A	30-60 min	0.5 - 15 min
Synchronous generation and inertia contribution	✓	✓	×	✓	×	✓	✓	✓
CAPEX	£4,000 - 5,000/kW	£3,600 - 4,500/kW	£250 - 950/kW	£600 - 5,500/kW	£600 -700/kW	N/A	£500 - 600/kW	£300 - 450/kW
Carbon Intensity	Zero	Zero	Zero	Zero	Low	Zero	High	High

*Source: Aurora Energy Research, *Refer to notes section*

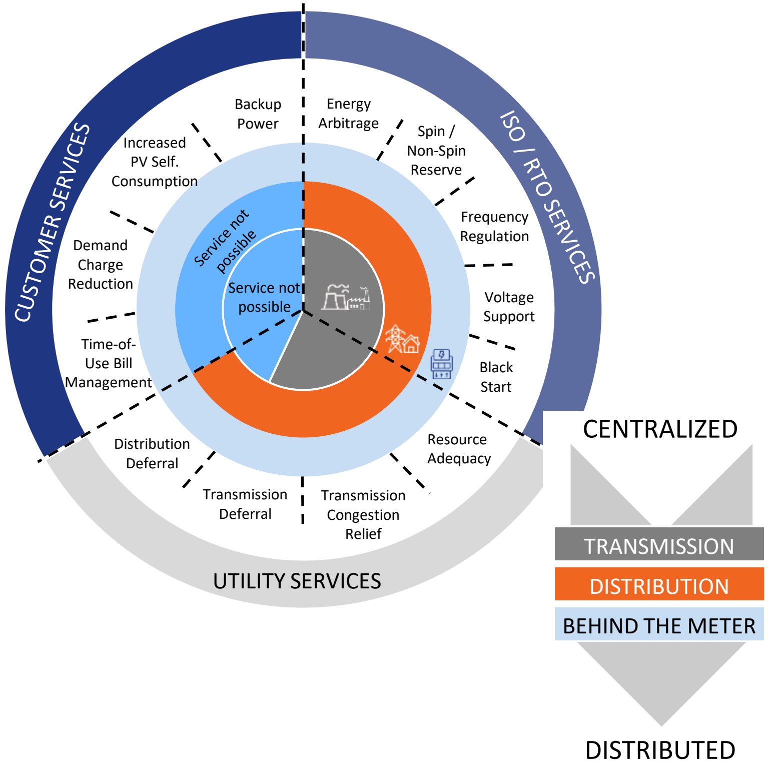
9. THE REVENUE STACK

The Revenue Stack (1/3)

Introduction

- Battery storage systems are most economical and viable only when multiple service opportunities are monetized. Lack of appropriate regulatory norms needed for batteries to participate in the bulk power markets along with incumbent generation resources are deferring the monetization potential
- With an expanding and gradually maturing energy storage market (though skewed), the issue of revenue stacking is gaining currency among policy and regulatory authorities. The right design of incentive structure can the market expect a wider participation of standalone battery storage developers

Service offerings of utility-scale battery systems across stakeholder groups in power system

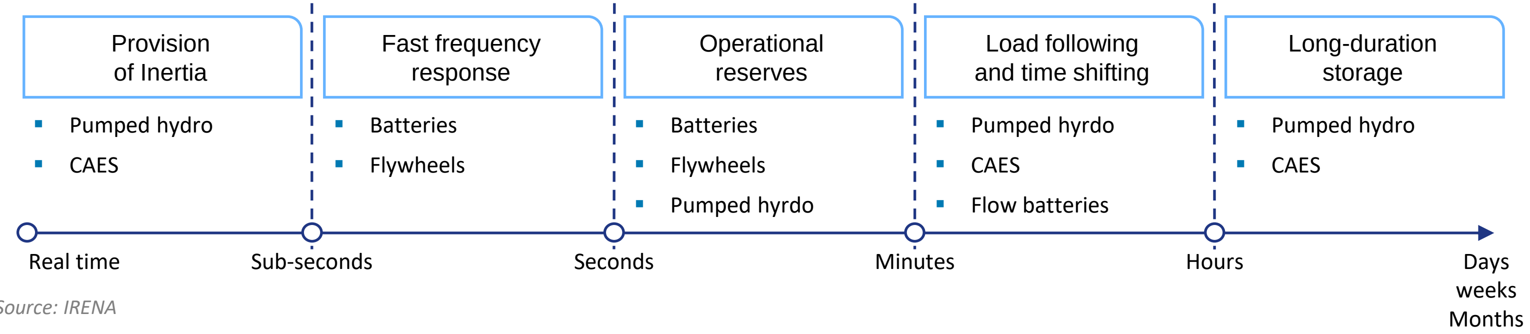


- There are about 13 identified revenue streams for battery storage systems
- Importantly, as the schematic of such revenue streams indicates, the utility-scale battery systems revenue structure is not limited to the grid-connected actors of the system
- Residential behind-the-meter systems (otherwise primarily for backup and resiliency for owner) can also be tapped-in for a grid's demand response mechanism with commensurate incentives for the asset usage

Source: Rocky Mountain Institute

The Revenue Stack (2/3)

Illustration of the System Services Available from Storage Systems Across a Timescale



Source: IRENA

Revenue Models in Focus

- Storage developers deploy several revenue models for their offerings to work out the value stack. With time, the revenue models changed as new project configurations emerged. For instance, the advent of co-located storage facilities (with renewable generation projects) enables revenue from multiple contracts and thus generates multiple layers of revenue
- Typically, fixed price contracts are preferred in the project financing market due to the cashflow visibility. For the utility contracting such a service, it enables a facility to draw power for peaking requirement or regulate the frequency imbalances or to inject reactive power in the system
- There are other fixed-price contract varieties where corporate end-users engage such capacities to either store and access power generated by a captive renewable energy generation project, or to provision for a backup power source to guard against potential outages. The end user pays a fixed fee for usage while the owner/sponsor of the project can also avail of any tax benefits arising from such arrangement
- Storage facilities paired with the renewable energy generation projects (wind and solar) can avail of a mix of fixed and variable revenue sources. The latter arise from the ability of storage facility to supply power (within the bilateral contract of generation) during peak period of high prices, thus also managing the risk of ensuring fixed volumes in the PPAs'. In cases of behind-the-meter storage facilities paired with solar power projects, owners can charge fees based on the savings against the electricity or demand charges on the customer's side
- Storage developers also offer ancillary services to the transmission service operators. Typically, operators procure reserves for many of the ancillary service requirements through auctions. In some other cases, few ancillary services such as voltage control could be sold at cost-based rates based on either the operator's or project owner's tariff schedule

The Revenue Stack (3/3)

Broad Categories of Energy Storage Business Models in Practice

	Generation-coupled asset	Grid asset	Merchant asset
Location	Generation	Transmission or Distribution network (Front-of-meter)	Anywhere
Ownership	Generators/IPPs	▪ Independent Storage Providers ▪ Regulated utilities	Independent Storage Providers
Dispatch	IPPs	System operators	Independent Storage Providers
Applications	▪ Firm power for Renewables ▪ Ramping for thermal power	All	Based on Market Development
Contract	Power Purchase Agreement	Tolling agreement	Market-based merchant revenues
Value maximization	**Medium** Dispatch priority is to maximize generator value not storage system's benefits	**Maximum** Grid operator is the single dispatcher maximizing the value in both upstream and downstream	**Low** Due to lack of multiple markets with the required depth in volume and participation
Bankability	**Medium** Volume uncertainty	**High** Fixed-price payment contract underlying the project	**Low** Revenue stream is merchant-based, varying hourly or yearly

Source: Sterlite Power

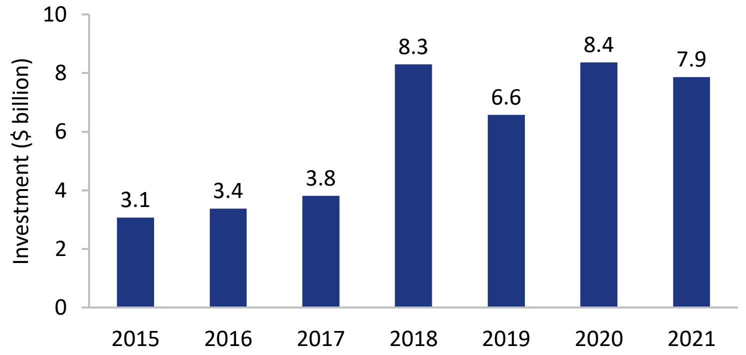
8. TRENDS AND DRIVERS

Trends & Drivers (1/4)

Introduction

- The energy storage market increasingly finds a greater investor interest because of the gradual technological improvements, enabling regulatory norms in some of the markets and the competitive costs that battery presents against competing grid-based generation
- An evolving industrial technology landscape enables progressive investment flow directed at the major storage technology configurations showing promise for commercialization

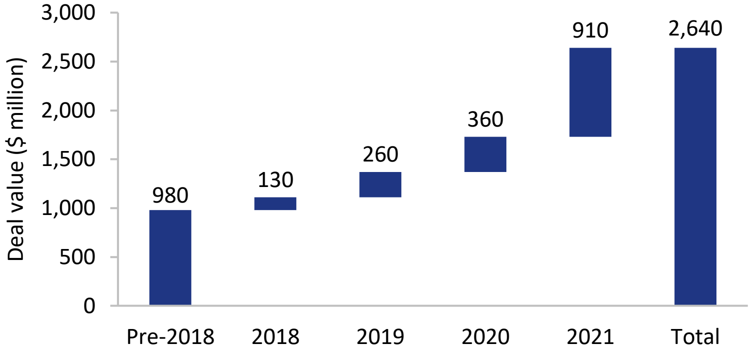
Investment Commitment towards Energy Storage Technologies



Source: BNEF

- The investments towards energy storage projects show a sharp jump, from an average $3.5 billion during 2015-2017 to roughly $8 billion during 2017-2021
- Investors are also extending commitments to the promising enterprises entering the markets as standalone energy storage service providers
- The investment scope remains untapped as numerous developers are unable to capitalize upon the full range of services that battery storage units can offer

Global Deals in the Long Duration Energy Storage Industry Segment

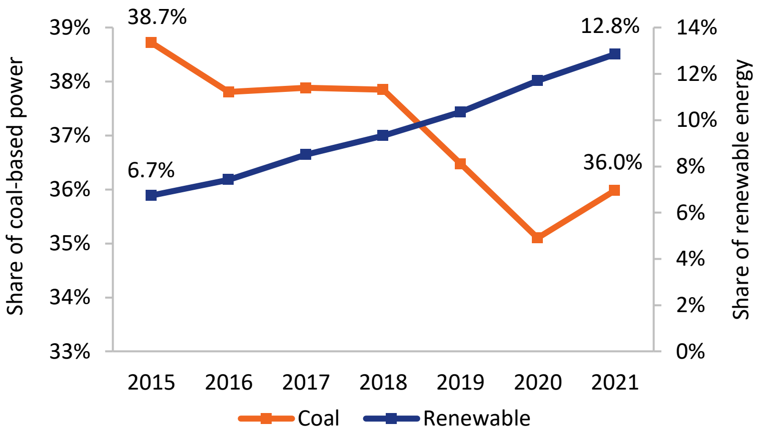


Note: Data excludes pumped storage hydropower
Source: McKinsey

- The rising need and criticality of the LDES technologies propelled investors interest in the space
- McKinsey estimates that over 260 LDES projects have been announced worldwide, and are at different stages of commercialization
- Thermal LDES holds the maximum share in the current technologies under testing or development

Trends & Drivers (2/4)

Relative Share of Coal and Renewable-based Power Generation



Source: BP Energy Statistics, 2022

- The historical trend till the end of 2021 shows a sharp decline in the share of coal-based power generation, indicating the gradual shift underway
- Closing coal-based power removes the baseload, dispatchable source of energy that is useful to balance against and integrate intermittent generation resources
- Looking forward, solutions are likely to be developed in terms of alternate generation such as in gas that has lower emissions and properties of grid stability

Requirement of Grid Upgrades and Modernization

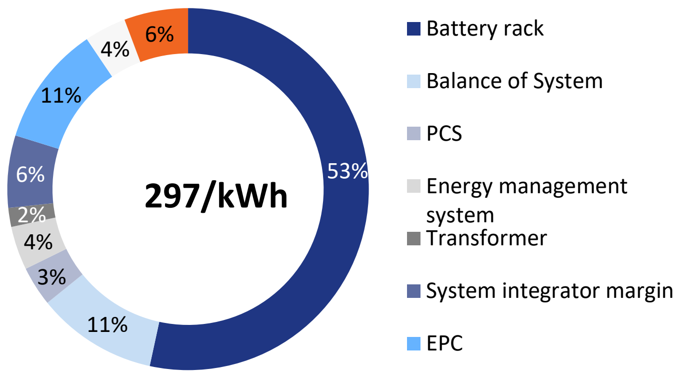
- The rapid and drastic energy transition underway imposes significant requirements on the existing power transmission infrastructure. Rise in distributed energy generation resources will pose a challenge for network planners to accurately project the load and demand
- As per the International Energy Agency (IEA), annual investment in the energy sector infrastructure and related technologies will need to rise from the existing $1 trillion to about $4 trillion by 2030. Delays in such investments carry a huge opportunity cost – delaying or cancelling future project prospects. During 2019 – 2021, the ISOs' transmission congestion costs rose from $2.7 billion to $7.2 billion
- In 2022, the US Department of Energy launched the 'Building a Better Grid' initiative, involving an outlay of $12.5 billion for grid reliability and related works. While public funding helps boost the investment momentum, vertically integrated utilities have drawn the capital expenditure plans to make use of the tax credits and other available support
- Increasingly, interconnectors are emerging as one of the counterbalancing factors in ensuring a flexible power system. The EU has the most significant project pipeline in this regard

Source: BNEF

Trends & Drivers (3/4)

Battery Supply and Costs

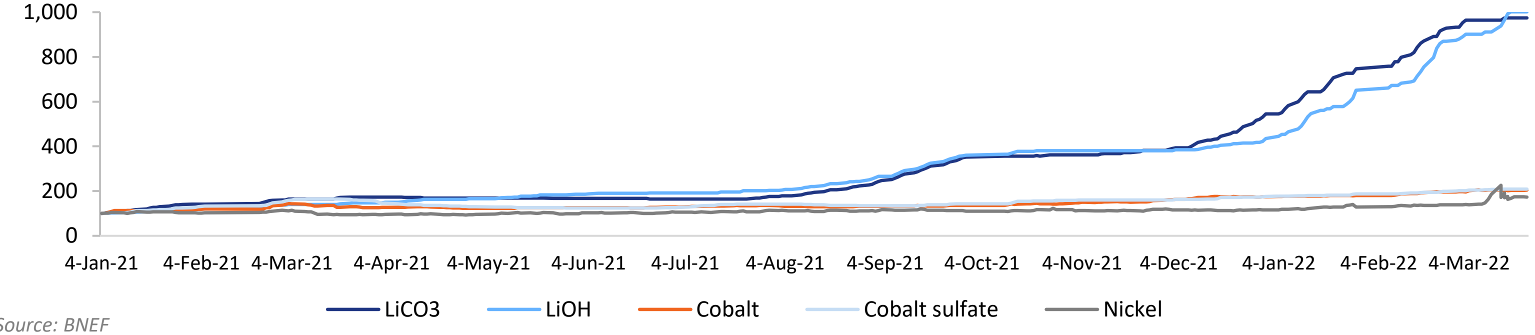
Average Capital Cost of a 4-hour AC Energy Storage at Beginning of Life



Source: BNEF

- The rapid decline in the battery costs, changes in system design, standardization in the duration systems are the most important factors in promotion of the storage business models
- BNEF estimates indicate average cost of a four-hour utility-scale battery storage system at $299/kWh (as of 2020 survey result). This is expected to decline further, to reach $167/kWh by 2030
- However, the projections around rationalization of the battery costs (based on Lithium and others) could be tempered by the global inflationary pressure
- Significant pressure comes from the electric vehicle demand segment that has a far bigger share in sourcing batteries than the power sector presently

Battery Metal Price Rise Between January 2021 and March 2022

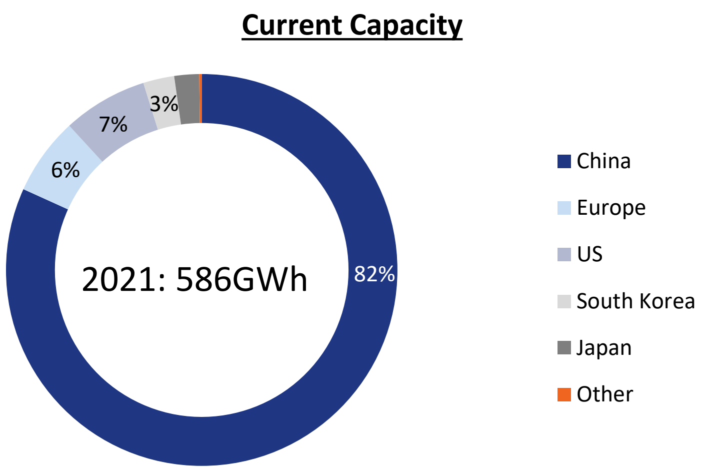


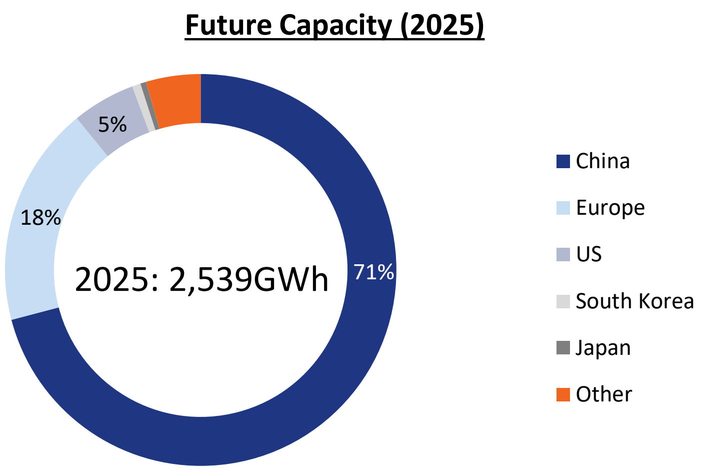
Source: BNEF

- The predominance of the Lithium-Ion technology in battery storage installations remains largely unchallenged in the market. However, the rising cost of Lithium and adjoining procurement and processing costs strengthen the case for sodium-ion batteries as the technology does not face the same challenges
- Nevertheless, multiple demand segments for Lithium-Ion technology have led to rapidly expanding manufacturing capacities, thus contributing to the outlook on further cost reductions. Furthermore, the need for a diversified supply chain could assume urgency, as geopolitical factors make it difficult to rely on select countries of competitive advantage

Trends & Drivers (4/4)

Lithium Cell Manufacturing Capacity by Plant Location Region





Source: BNEF

- One striking element of the upcoming manufacturing capacity is the diversification of base underway
- China still leads the way while the European region is poised to massively enhance its indigenous production base. In the last two years, battery production capacity tripled in Europe with over 38 Gigafactories already planned in the region
- In the last two years, battery production capacity tripled in Europe
- Among other technologies, lately, sodium-ion batteries have come to the forefront in mass production and commercialization for its competitive advantage over Lithium-Ion in terms of raw material sourcing and costs
- Some of the leading manufacturers such as CATL are in the process of developing these batteries at scale

9. OUTLOOK

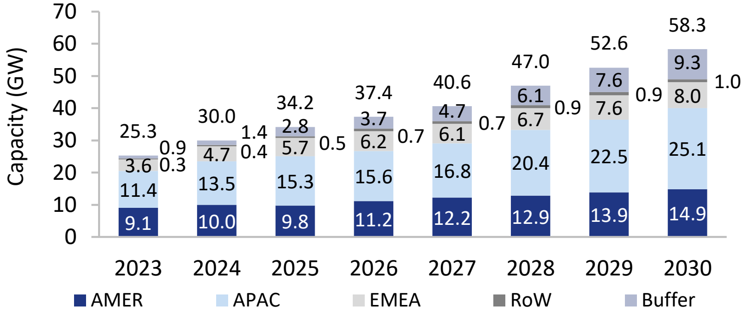
Outlook (1/2)

Introduction

- Renewable energy penetration, rapid decline in battery costs, and the regulatory changes in the power markets act as optimistic factors driving the energy storage market. Project pipelines and the new technologies under consideration indicate a wide scope of the projected opportunity
- Uncertainties could be partially offset by the factors such as commercialization of new technologies, rise in merchant storage developers' participation, and new business models to capitalize on the revenue stacking capabilities of battery storage units

Storage Capacity Growth

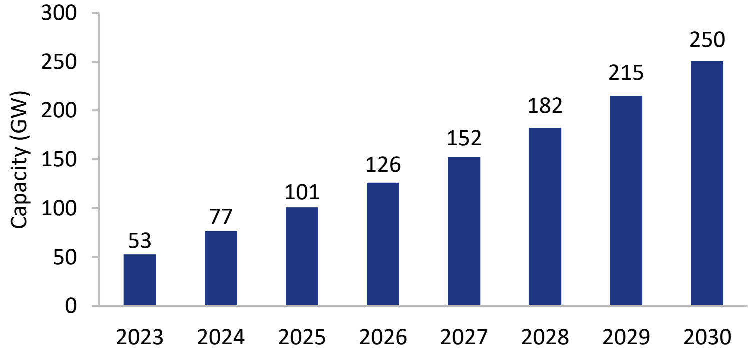
Projected Global Annual Battery Storage Installation



Note: Buffer is an estimate/headroom that is not explicitly allocated to any specific application.
Source: BNEF

- BNEF projections indicate a five-fold rise in the annual battery storage installations by 2030, compared to what was installed in 2021
- US and China drive the bulk of storage capacity growth during the forecasted period
- Growth is relatively muted in the EMEA region. European countries' deployment of transmission interconnector capacities tends to offset the scope of storage capacities

Projected Cumulative Utility-scale Battery Storage Capacity



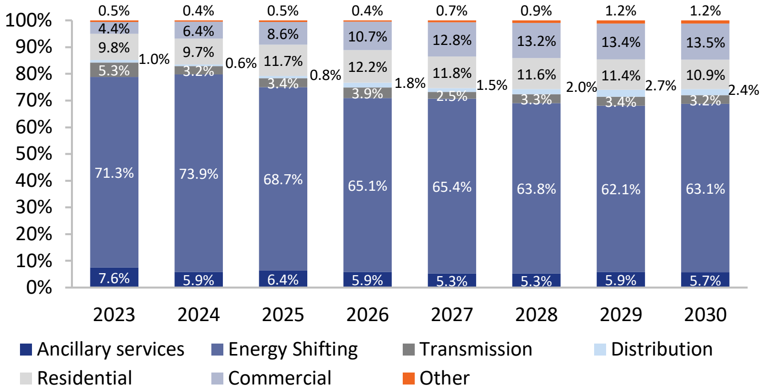
Source: BNEF

- The utility-scale energy storage segment will have the most significant contribution in enabling the energy transition across power systems globally
- Costs could be an important factor to contend with in the projected utility-scale segment growth. Global inflationary pressures and rise in commodity prices have already impacted many energy storage projects
- The revenue model of the large-scale batteries continues to be constrained by behind the curve regulatory frameworks

Outlook (2/2)

Changing Application Mix of Storage Capacity

Projected Application Mix of Installed Battery Storage Capacity



Note: Excludes pumped hydro projects. At a project level, if multiple applications are selected, the capacity is divided equally among them. Energy shifting refers to using utility-scale energy storage to perform arbitrage and to provide reliable capacity to meet peak system demand.
Source: BNEF

- Energy arbitrage (or energy shifting) is already the dominant use of battery storage assets. About 60% of the storage capacity addition by the end of 2022 is expected to be devoted to the arbitrage role
- BNEF estimates point to 15% of total battery storage deployments directed at the ancillary services. However high deployment rate may not sustain over time due to commensurate moderation in prices of ancillary services
- The residential and commercial storage installations are projected to rise in importance which will be led by favourable policies in rooftop solar and gradual phasing out of the provision of net metering

Emerging Role of Long Duration Energy Storage ("LDES")

Long Duration Energy Technologies in Focus for Near-term Deployment

	Construction time (years)	Market Readiness	Location Fexibility	Key value areas			
				Congestion relief	Energy Arbitrage	Ancillary services	Operating cost
Pumped hydro storage	3-8	●	○	◕	◕	Inertia, reactive power, SCL, Black Start	◕
Li-ion batteries	1-2	◔	●	◔	◕	Frequency	◑
Liquid Air	2	◑	●	◕	◑	Inertia, reactive power, SCL, Black Start	◑
Flow batteries	0.5-2	◑	●	◑	◕	Frequency, reserve, inertia, reactive power	◕
Compressed air	3-5	◑	◑	◕	◔	Inertia, reactive power, SCL, Black Start	◑
Gravitational	2	◔	◑	◕	◕	Frequency, reserve, Black Start	◑
Thermal (Molten salt)	2	◕	◑	◕	◔	Inertia, reactive power, SCL, Black Start	◕
Hydrogen to power	3-4	◑	◔	◕	◑	Inertia, reactive power, SCL, Black Start	◔

● More Applicable
○ Less Applicable

Note: 1) Short duration Li batteries are market ready, long duration is not yet seen to be established in the market; 2) Suitable power conditioning system required; 3) Molten salt refers to concentrated solar power with storage; 4) Hydrogen-to power refers to CCGT only; 5) Under operating cost category, a full Harvey ball implies favourable operating costs, i.e., low.
Source: Aurora Energy Research

- Changing energy transition scenario and system flexibility demands make LDES a critical resource for the grid operators
- Within the leading LDES technologies, a few are already operational but are constrained by limitations in location or deployment
- While the commercial deployment remains far, the select set of leading technologies are likely to receive greater funding support. McKinsey's report on LDES predicts investments to reach $3 trillion by 2040

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