Global Energy Storage Market Review

2022

PAN AMERICAN FINANCE

About

The report provides an insight into the Global Energy Storage market. The findings of the report are based on research conducted by Pan American Finance (PAF) and its research partner Alchemy Research and Analytics. The report provides an overview of the Global Energy Storage industry with insights on prevailing market conditions encompassing recent trends and drivers, challenges, and outlook in major countries across Europe and Americas. The report starts with a high-level view on the dynamics of the industry, touching upon the regional variations and analysing the implications of the same. It then profiles the major markets country-wise, to provide a holistic view of the state of the industry in these countries, highlighting the growth opportunities, demand drivers and prevalent challenges. Macroeconomic data was sourced from the publications of multilateral institutions such as the International Monetary Fund (IMF). The industry-specific data is attributed to industry associations, Government authorities / statistical departments, Bloomberg New Energy Finance (BNEF) and International Energy Agency (IEA). This was supplemented by news reports, trade journals and related sources.

The report is an outcome of a collaboration between PAF and its research partner Alchemy Research and Analytics and was completed between September and November 2022.

We would like to thank the following executives for their contribution in preparing the report:

- L. Warren Pimm, Partner and Sr. Managing Director - Pan American Finance
- Jeffrey Safford, Managing Director - Pan American Finance
- Tapas Bhowmik, Senior Manager - Alchemy Research and Analytics
- Souradeep Basu, Associate Manager – Alchemy Research and Analytics
- Ankan Banerjee, Senior Analyst - Alchemy Research and Analytics
- Maurya Mukherjee, Senior Analyst – Alchemy Research and Analytics

Introduction

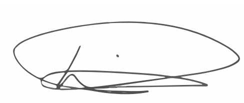
The global energy markets face significant volatilities due to a rise in energy demand and the geopolitical risks. At the same time, there are pressing concerns of climate change mitigation, for which governments and businesses have committed to steep decarbonization targets. The requirements are much higher than this since the ongoing measures are now somewhat confirmed to fall short of the 1.5^{0}C global warming threshold. The scenario projections thus must factor-in drastic shifts in the energy systems.

One such clear trend is the shift of global energy consumption mix towards electrification or the power sector. Electricity demand will thus rise manifold, while its supply-side heads for a 80%-90% renewable energy penetration (~2050 projection). Many countries, especially those of the developed and mature energy markets, are in a transitory phase of adjusting the power systems – in effect creating room for the flexibility needed in managing intermittent and distributed power generation.

The US and European region together could contribute to retiring about 125GW of coal and nuclear power capacity over the next 10-15 years. Renewable energy will fill-in for the gap. In most of the countries, the conventional energy generation is likely to be relegated to the role of grid support and backup against the rise in intermittent generation in the grid. The transition to a decarbonized power sector will depend on a timely and adequate provision of options of flexibility in grid supply, such as in terms of interconnectors, energy storage, peaking hydropower and demand-side response among others. Market prices will play an important part to signal incentives for potential investors. Power markets pricing-in the demand for major attributes like flexibility, emissions, and reliability could make the difference in attracting investments.

The purpose of PAF's Annual Primer series is to provide a high-level view of demand drivers, opportunities, challenges and outlook in major markets. In doing so, the reports aim to put together the salient points of global industry trends and country-specific market factors critical to success for all potential market entrants.

We hope you will enjoy reading our report on the Global Energy Storage Market, and we look forward to briefing you on other industries and technologies in clean energy space in the time to come.



L. Warren Pimm, CFA

Partner, & Sr. Managing Director

Pan American Finance

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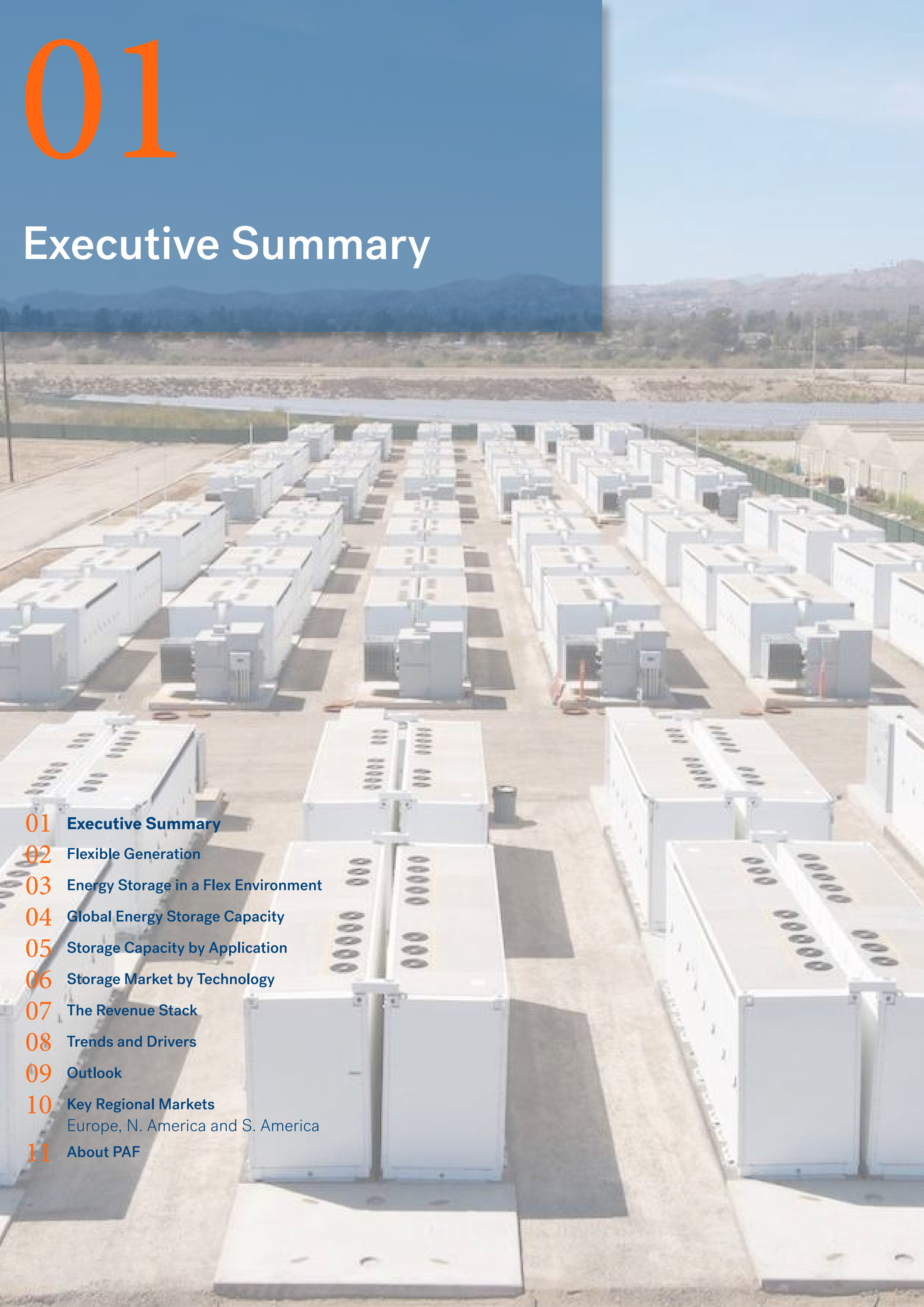


Executive Summary

Network operators increasingly seek capabilities for a flexible power system, to accommodate the share of renewable energy projected at a 90% share of total generation by 2050. The ideal mix of the flexible resources will be based on the respective techno-economic merits and local grid constraints. Importantly, the conventional grid management practices are gradually giving way to those involving a decentralized grid framework. The energy storage resources feature prominently in the emerging framework.

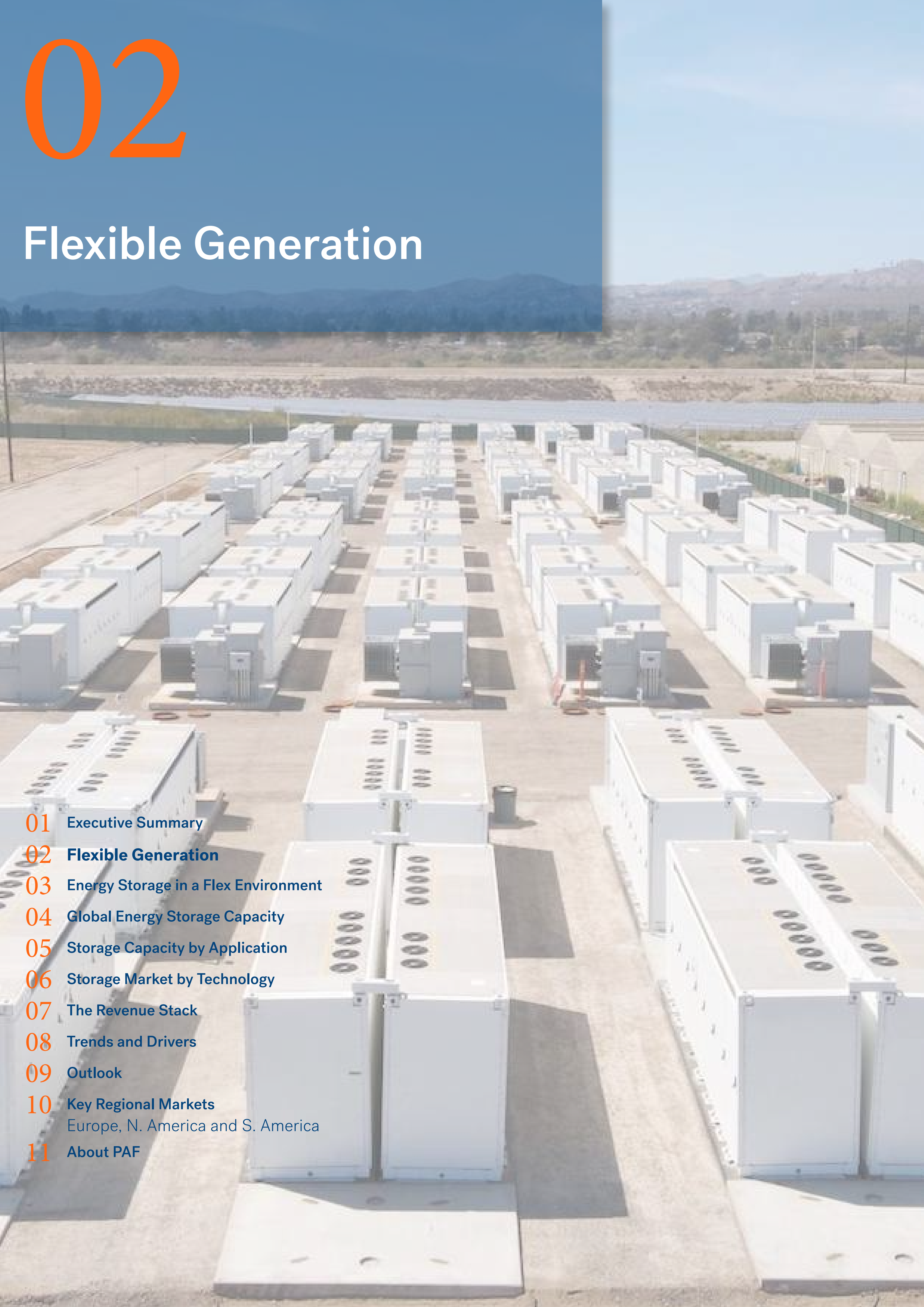
Energy storage resources, comprising pumped hydropower and batteries, offer competitive option of grid management in combination with options such as combined cycle gas turbine plants or demand response. Emission norms associated with generation capacities add to the competitive edge in storage resources. In the US market for instance, batteries already present a competitive alternate to the gas-based plants. Further rationalization in the costs of battery technologies could tilt the balance sharply.

Commercialization and economies of scale have helped Lithium-ion to emerge as the predominant technology choice in the installed battery storage capacity worth 27GW by the end of 2021. Battery-based storage grew by more than three times between 2018 and 2021. An even faster growth could have been achieved, were it not for the lagged regulatory position in the power markets. More than two-thirds of the battery storage capacity is from the utility-scale segment that caters to the power transmission sector. This is the most critical of the deployment roles for battery storage as utilities and transmission operators navigate the energy transition in their operations.

The trend in battery deployment by applications confirms their active role in the grids. Energy arbitrage is increasingly the most frequent deployment for batteries, as grids manage wide differentials in their peak and off-peak energy prices (often reflecting influx of intermittent energy). Overall, frequency regulation, as part of grid ancillary services remains the popular use for battery storage by operators. This is in line with the Lithium-Ion battery technology configuration most of which is for a 4 hours or lesser duration. In some mature markets such as those of the US and the UK, frequency regulation is somewhat saturated. In the nascent markets, the evolving regulations could start with this segment before moving to others.

With rising complexity and imbalances on the horizon, it is the long duration energy storage (LDES) that is finding the maximum attention from the operators and regulators alike. But battery-based LDES is yet to be established for technology maturity or economics. Investor focus has thus risen sharply on this part, as commercialization could make rapid dent in the global storage market and the power system at large. As things stand, 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.

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. Global macroeconomic uncertainties such as in terms logistics and inflationary pressures could act as temporary dampeners in some of the storage markets. Yet the growth prospects in the market strongly rest on the imminent shift in power systems and its energy delivery.



02

Flexible Generation

Flexible Generation

The Case for Flexible Generation

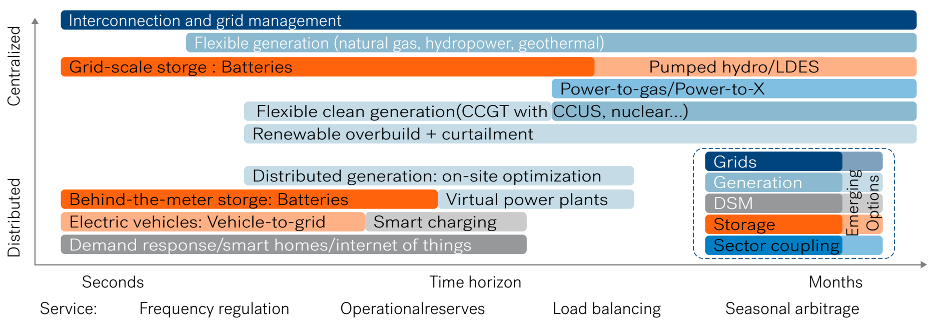
Energy Transition and Implication on Grid Management

Most of the power systems worldwide are seeking ways to keep up with a transitionary phase affected by rising renewable/intermittent energy generation and carbon emission policy targets. Both are poised to change the standard processes of power market transactions and network reliability. The roadmap and approaches might vary based on the specific country-specific or local contexts. But the direction points to a new and yet-untested arrangement where multiple flexible generation units operate and interact in a suite of options to enable a balanced system.

74% share of renewables in total primary energy supply by 2050

IRENA's World Energy Outlook 2022 points to 74% share of renewables in the total primary energy supply by 2050. By that forecasted year, renewables' share in total electricity generation is 90%. The integration of variable energy resources in such a scenario becomes a complex balancing exercise. Grid reinforcement and strengthening is one predictable route at ensuring preparedness of the transmission network. Yet the flexible generation assets have a critical role. There is a matrix of flexible generation systems positioned by their respective roles in the grid functioning. Gas-based generation for instance continues to have an outsized role in such capacity planning. Yet, batteries are gradually displacing gas-based plants in several wholesale markets (such as in the US) due to the commercials.

Tentative Positioning of Flexible Power Generation Systems



Notes: LDES= long-duration energy storage CCCT= combined-cycle gas turbine, CCUS=carbon capture, utilization, and storage, DSM= demand-side management, Power-to-gas refers to the use of electric power to produce gaseous fuels, such as the use of electrolysis to produce hydrogen. Power-to-X refers to various processes that convert electricity into non-power resources, such as power-to- chemicals, power-to-fuel, power-to-food, and more
Source: S&P Global Commodity Insights, formerly IHS Markit

Market Incentives and Feasible Options for Operators

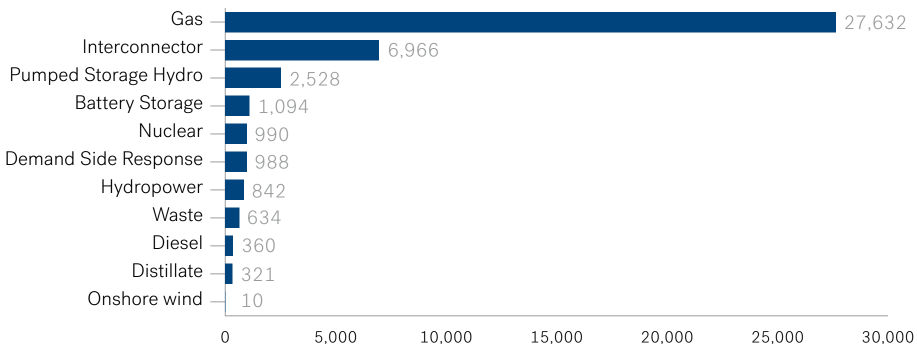
Despite the potential offered through emerging energy storage technologies, the overall suite of options before network operators are often limited. While this could be a reflection of market incentives deterring storage capacities, the flexible generation capacity options for grid operators continues to be a mix of the new and old generation technologies. Capacity markets of the power systems (contracted for contingency ahead of time) is one flexible generation segment that operators set aside to manage volatility. Incentives are the most important factor here.

Batteries, for the existing solutions commercially available/feasible, are yet to make a dent in this part of the power market. As the 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 combined cycle gas turbine. Batteries for now are most useful in the role of price arbitrage (peak and off-peak price in the grid).

With rationalization in the price of batteries and the rise in renewable energy penetration, it is likely that the existing balance changes. Moreover, as larger capacities switch off from the grid (phasing out of the conventional plants), the case for alternatives in battery storage will strengthen through better prices.

Battery price rationalization & rise in renewable energy penetration will strengthen the battery storage sector

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



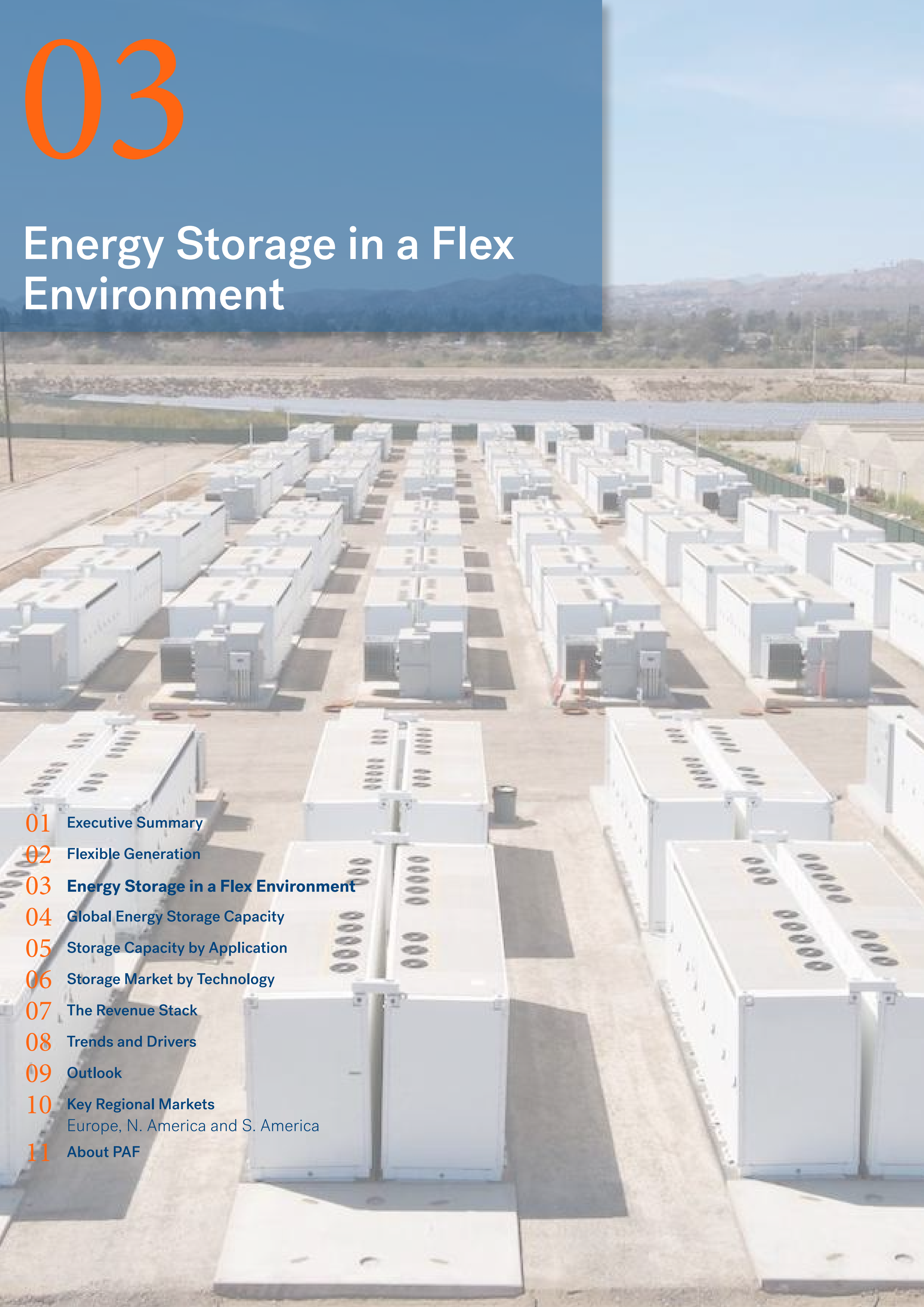
Notes: Data refers to the four year ahead capacity market auction results published as of February 2022
Source: National Grid Electricity System Operator

The Emerging and Impending Shift to a Decentralized Grid Management

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. Such a structure entails a fundamental shift, wherein generation units are dispersed and close to consumption, while storage (batteries) are placed near generation assets. Transmission, in such a scheme, addresses major systemic imbalances instead of just meeting power dispatch.

The flexibility lent from decentralized networks has resulted in one such key change in flexible generation, in terms of Virtual Power Plants (VPP). Typically, VPPs involve distributed energy resources (mostly wind, solar and combined heat and power units) linked through cloud computing. The advent of 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. The company draws upon this capacity across wind, solar, hydropower, and bioenergy and has electricity consumers, prosumers, and battery storage in network.

There are other models as well in consideration, as modelling scenarios of renewable energy penetration exceeding 50% of total supply may render most of the existing grid management options redundant. The Sector Coupling model is one important emerging option in this context. It refers to the renewable energy-based electrification of end-uses, as a cost-effective way of providing energy services in the network. The benefit of such an arrangement lies in enabling decarbonized setup while tapping into the abundance of renewable energy generation. The flip-side though is the infrastructural and technological prerequisites for large-scale implementation. The decentralized power operations in countries such as Denmark present some indications of such models. The country's CHP plants were incentivized for flexibility (exposing them to the power market price variations). It helped sector-coupling of heat and power, as CHP plants' power output varied (in terms of change in power-to-heat ratio) based on market prices reflecting demand.



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Energy Storage in a Flex Environment

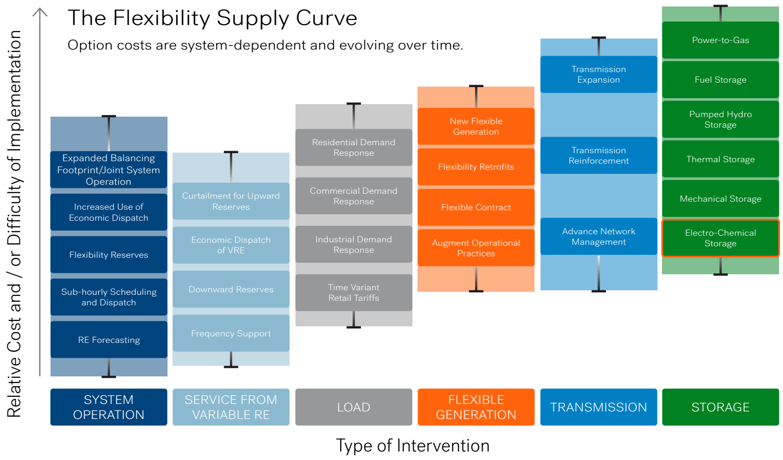
Energy Storage in a Flex Environment

The emerging flexible power system requirements across countries place a critical role for the energy storage capacities to work in tandem with other generation sources of the power mix. To be sure, energy storage units are expected to support and complement other components of the power system with change in the demand scenario. In specific terms, this implies energy storage capacities operating within a mix of resources such as combined cycle gas turbines (CCGT), reservoir hydropower, or demand-side management to meet the situational needs (frequency regulation, load balance, operational reserves, etc.).

For most part, the narrative for energy storage and flexibility is limited to the power transmission system's reliability and balance. Though restrictive, the reason for such focus is because of the drastic changes in the transmission network. 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. Compounding matters further are policies mandating a phaseout of fossil-fuel and nuclear power.

Decline in Lithium-Ion cost & fast-ramping batteries will gradually displace gas based peaking plants

The Flexibility Supply Curve



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

The commercially deployed storage systems of pumped hydropower and batteries fulfill many of the gaps to meet flexibility requirements. Helped by the sharp decline in cost of Lithium-Ion, fast-ramping batteries have progressively displaced gas-based peaking plants in most of the mature/developed markets. The US-based NREL study on storage deployment reaffirmed the competitive role of batteries as the new peaking capacities even without a carbon emissions policy. Yet, such conclusions are sensitive to the local market compensation and incentive structure for storage and overall power mix. In the US for instance, at an all-in cost of $132/MWh, a typical four-hour battery deployed in the grid appeared competitive to the global gas-based peaker plant average at $173/MWh. A contrasting picture is found in the Indian power market, where about 25GW worth of stranded gas-based capacity and a nascent storage market skews the balance in favour of gas-based peaking (to balance grid or support renewable energy dispatch).

Among the storage technologies with commercial deployment at scale, the near to medium-term visibility is the strongest for the Lithium-Ion battery units. Yet, the legacy base of hydropower generation is an important resource for power system flexibility. Lately, hydropower plants, especially the reservoir-based variety, find a renewed currency for their capabilities in managing variable demand, intermittency, and ensuring an emission-free footprint. To place this in context, it is noteworthy that in US (also the largest global energy storage market), pumped hydropower capacity

Energy Storage in a Flex Environment

meets over 90% of the bulk storage needs. The US market's integrated resource plans in major power markets (such as California's) indicate that the emission targets for 2030 entails a greater demand for the 4+ hours' storage segment to moderate the gross and net peak demand. With retirement of gas and nuclear power units, hydropower capacities are even more relevant for the flexible generation demand.

It is in fact the progress towards long-term net zero emissions targets that creates the maximum stress of flexibility for the power systems. The emphasis, as a result, is on Long Duration Energy Storage (LDES). In a generic sense, LDES connotes the storage segment of 4 hours and above. The demand is for competitive technologies that could be provisioned for multiple hours, days or weeks to support the system exigencies. Understandably the investor interest is high in LDES (3.5 times rise in global deals during 2018-2021) even as commercial scale is some time away. Pilot projects in select 4-5 major technologies are helping establish viability and use-cases that include off-grid applications as well. The studies also indicate that the potential LDES deployment could emerge as low-cost flexibility solution in some situations, and a complementary resource in others. Some of the leading novel LDES technology categories presently in contention include Compressed Air Energy Storage (China's recent 100MW capacity is the largest), molten salts (has been in limited use through concentrating solar power), power-to-gas systems (such as power-to-hydrogen-to-power, among the leading ones), and metal-air batteries, among others.

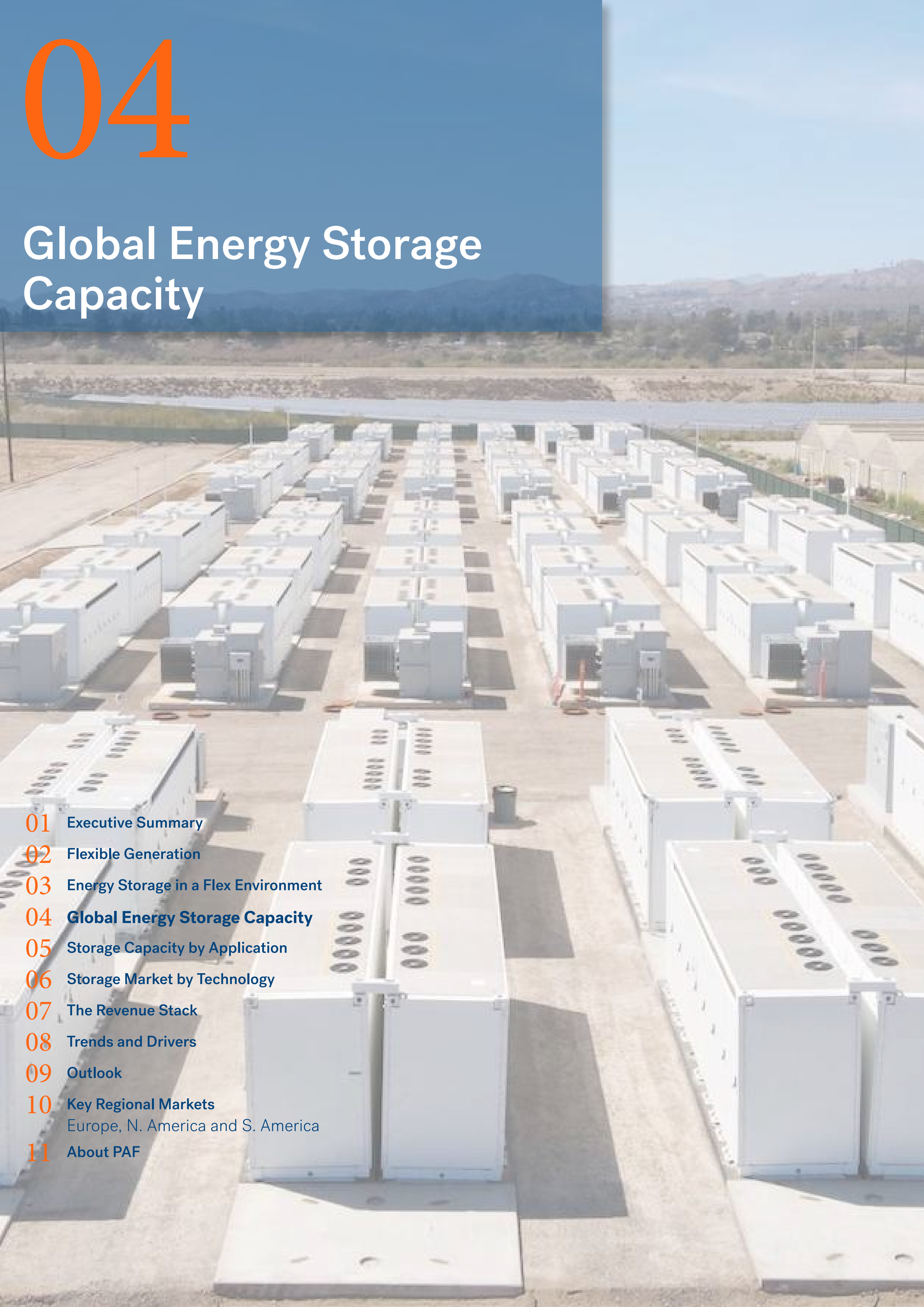
Demand for 4+ hours' storage segment paving the way for Long Duration Energy Storage

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	✓				✓	

✓ Solution ✓ (partial) Partial Solution

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



04

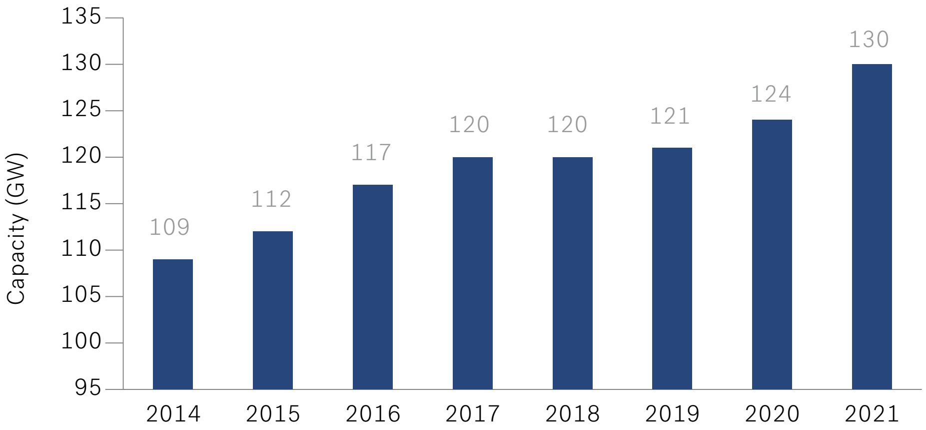
Global Energy Storage Capacity

Global Energy Storage Capacity

The scope of energy storage technologies has grown far beyond the customary integration requirements related to 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. With conducive drivers in regulations (in specific power markets' norms) and economies of scale in technology (primarily Lithium-Ion so far), the storage market growth accelerated in most of the mature and large-sized energy markets. Much of the capacity growth can be attributed to a demand-pull (such as incentives in bulk power market or tax benefits for storage hybrids) of the emerging transitory phase of energy sector worldwide.

Grid-scale batteries hold the key in capacity growth

Global Pumped Storage Hydropower Capacity



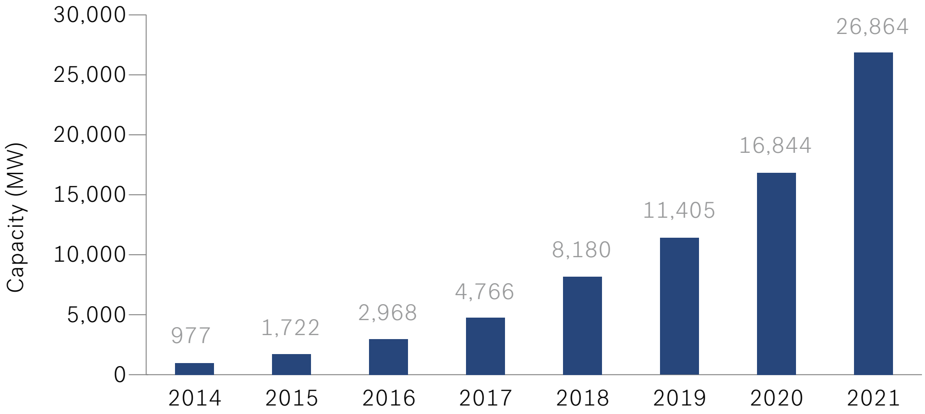
Source: IRENA

The trend in pumped storage hydropower partly reflects the role of demand in the market. This segment of energy storage is a legacy technology that still corners more than four-fifths of the global energy storage capacity. Its preference however has waned over the years due to the restrictions of project siting, gestation period and the resulting high capital costs. Few capacities came onstream as a result. The period 2016-2019 reflects the stagnant phase with negligible incremental capacities. The underlying market demand however could change this trend for the better. There is an uptick observed since 2020 that also matches the rapid rise in renewable energy penetration in the major storage markets (US and China among others). With steep targets of net-zero energy transition, pumped storage hydropower may be on revival path. In April 2022, the world's largest pumped storage hydro plant (3.6GW) was commissioned in China. More of such capacities are in fray even as China leads the race in battery storage. This is because, with the rise in demand for clean and flexible energy generation, grid-scale pumped storage generation is more likely to offer competitive costs at the margin.

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. It has significant and competing demand segments in the power transmission, residential solar units, consumer electronics and the electric vehicles. The expansion in manufacturing capacities helped achieve a rationalisation in costs that is otherwise unmatched so far in other storage technology options. Such a situation of single-technology dominance could change soon as other battery configurations (compressed air, ferrous, and thermal) are commercialized. Grid-scale batteries hold the key in 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. Major US states of California and Texas are notable examples of capacity growth propelled by the enabling changes in market participation norms.

Global Energy Storage Capacity

Cumulative Installed Battery Storage Capacity



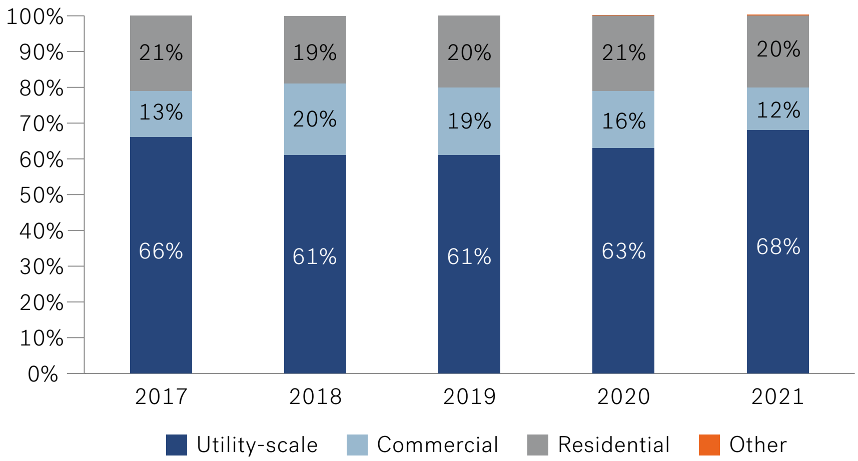
Source: BNEF

High growth possibility through residential & commercial storage segment exploitation

The trend in capacity deployment by major segments indicates the continued importance of grid-scale batteries. The growth achieved so far is still a relatively muted one, considering that many countries are yet to frame the relevant regulations (including legal definition of energy storage) for this industry. Most of the utilities' battery deployments have been towards frequency regulation (battery storage intervene for very short durations to stablise frequency deviations). The emerging and popular demand though is the energy arbitrage, wherein the battery units serve the power market for difference between the peak and off-peak energy demand.

The residential and commercial storage segments are relatively underrated in the ongoing energy storage narrative. This is because the growth in these segment, especially residential, has been limited to select demand pockets. Germany, for instance, has an energy storage market led primarily by the residential batteries. This derives from the German solar power market, where the rooftop and small-scale residential solar PV units drove the overall solar energy penetration. Europe as a region is characterized by the leading role of residential energy storage. This is gradually poised to grow, not only from the grid-connected units, but also the off-grid or behind-the-meter segment.

Trend in the 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

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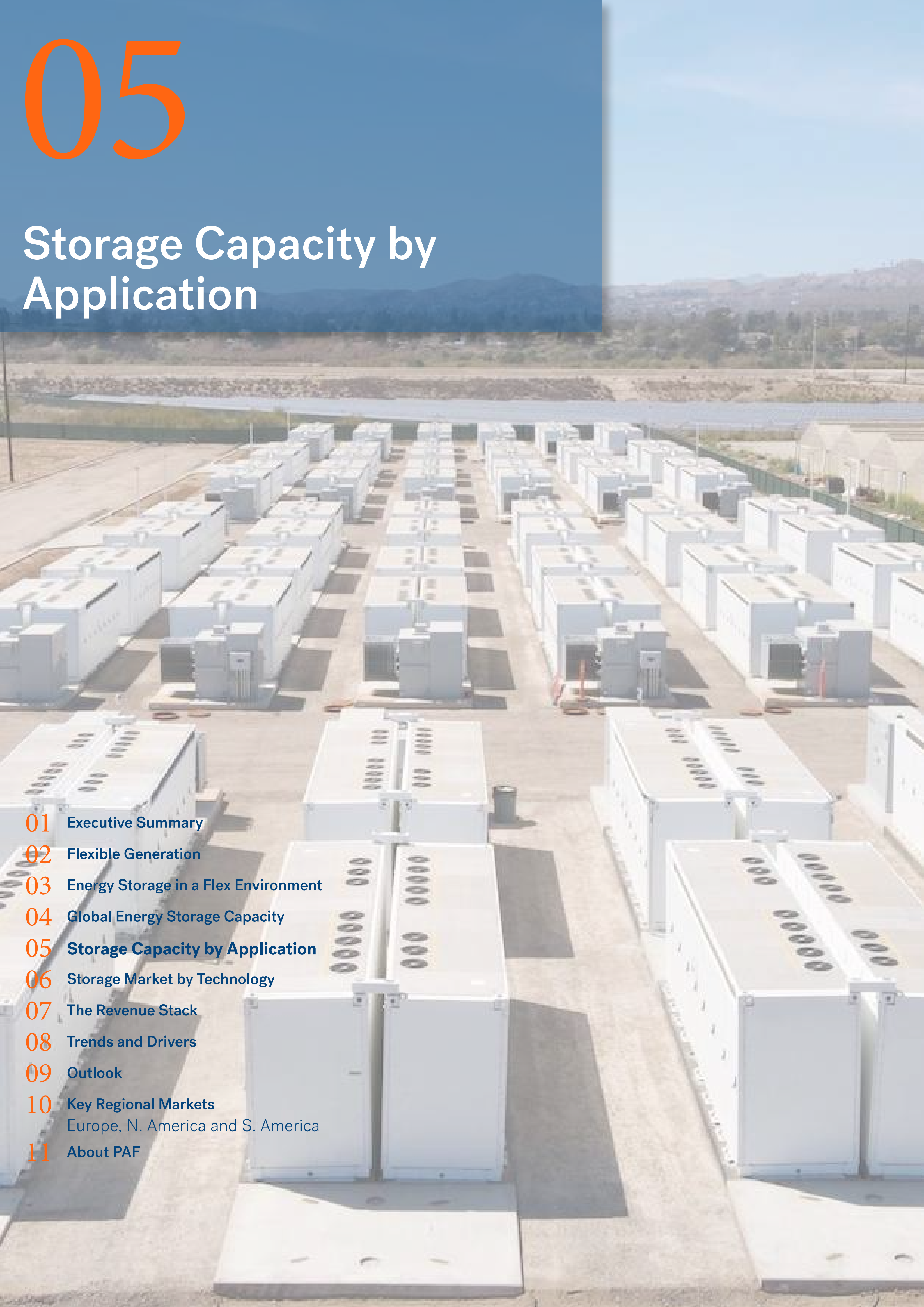
Storage Capacity by Application

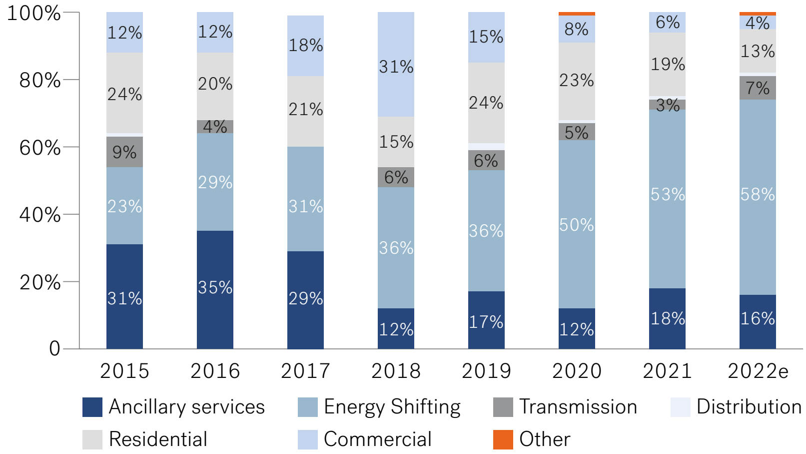


Storage Capacity by Application

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. It also helps that regulatory changes are gradually enabling a fair share of battery storage units in the overall power market transactions. Market maturity though is a factor to contend with – not all countries are at the same level in terms of policy and regulatory response. Developers and the investor response is thus proportionate to the visible incentives and returns. The largest markets of US and China continue to show most of the evidence on progress. Europe meanwhile appears to be catching on with gradual regulatory measures.

Uneven developer and investor response due to lumpy progress on regulatory changes

Trend in Share of Grid-Scale Battery Storage by Applications



Note (a) The data excludes pumped hydro power storage, and thus peaking power does not feature among above applications.

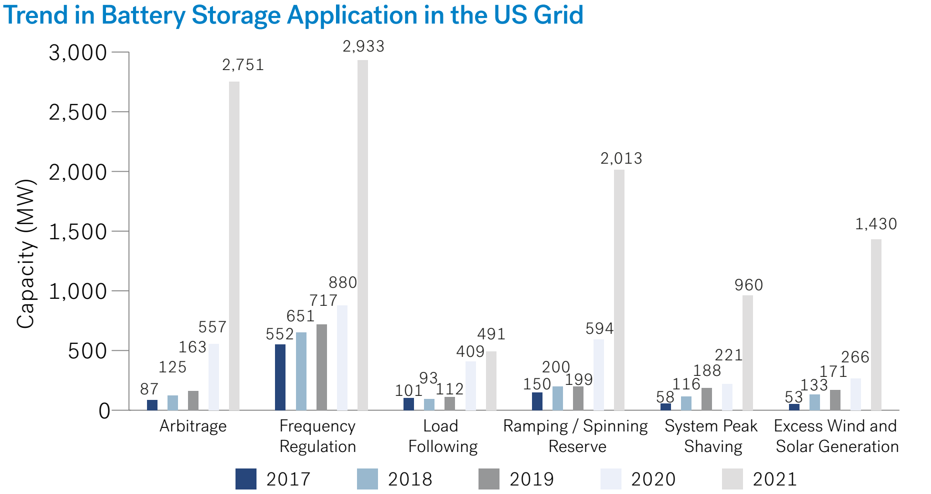
Note (b) Energy shifting refers to price arbitrage role of storage units, to supply during peak hours and take advantage of the price differential.

Source: BNEF

Frequency regulation has been an important application (among other grid ancillary services) in majority of the energy storage markets. Batteries are well suited in such a grid stability role because of inherent advantages such as near-instantaneous response to power surges (there is no startup time). For most of the storage developers, frequency regulation is the most common revenue stack category.

In the US, the share of operational battery storage facilities devoted to frequency regulation stood at 60% by the end of 2021. In April 2022, the UK's energy storage market launched the auction for a new frequency regulation service, namely Dynamic Regulation, by the National Grid. Earlier in October 2020, Dynamic Containment service was launched, as part of the same frequency regulation category. The latest launch was meant to aid correction of continuous but small frequency deviations in the grid.

Storage Capacity by Application



Note: Survey data includes capacity deployment reported for more than one application

Source: US Energy Information Administration (Annual Generation Survey reports)

Frequency regulation remains as the mainstay among the list of applications in major energy storage markets

While frequency regulation remains as 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. The US Energy Information Administration's (EIA) annual generation survey attests to the shift underway. During 2017-2021, the survey respondents confirmed a disproportionate rise in deployment of battery storage for price arbitrage. Rising renewable energy penetration is one major factor in such an emerging trend.

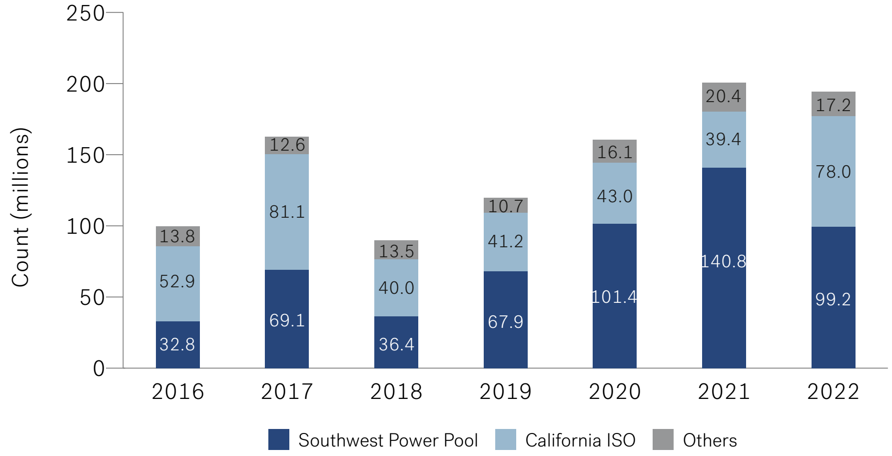
A rise in renewable energy power injection in the grid changes the usual shape of day-ahead grid price trend curve. Typically, it leads to lower daytime prices. Battery storage systems are better-placed to capitalize upon the spread – charging during the low-price daytime hours and discharging during the higher price time slots. Thus, in case of the US market, such a deployment is observed in the states of California where the share of renewables has been higher than the country average. Conversely, it has an understated role in the US PJM Interconnection region where renewables are yet to assume a major role.

Emission norms imposed by regulators in most of the markets increasingly make the conventional gas-based peaking generation capacities unsuitable. This is where battery storage units fit the requirement. It is thus observed that batteries are progressively filling in the category of spinning reserves that help the operators ensure managing load fluctuations.

The factor of emissions has also played the role in the grid operators' capacity market auctions (generation capacities provisioned 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. Italian operator Terna's capacity auction in February 2022, for instance, involves 1.5GW of new capacities of which two-thirds are to be met through battery-based units.

Storage Capacity by Application

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)

Capacity deferral will drive long-term energy storage value

Participation of batteries in the energy wholesale markets (through capacity market auctions) is adding to the support that ancillary services provide in the battery developers' revenue stack. Regulatory changes as done in US and Europe to allow battery systems compete in the wholesale markets helps reinforcing the case. To be sure, the experience shows that there are challenges in stabilizing the battery systems in the mix (such as imbalances in fast-ramping and slow-ramping resources, dispatch parameters, etc.). Yet the benefits outweigh the costs.

The path to regulatory measures in market design is a protracted one, as observed in several countries. In the meantime, the storage developers seek alternative applications for efficient capacity use. The network bottlenecks offer an indicator of another emerging opportunity. Massachusetts Institute of Technology's (MIT) research publication in this regard (as of 2020, under MIT Energy Initiative) confirmed an important hypothesis. The study revealed that capacity deferral is the primary source of long-term energy storage value. The deferral includes both transmission and distribution infrastructure and the expensive gas-based generation (usually as peaker capacity).

As grid infrastructure lags new wind and solar generation, batteries may be the only intermediate option. A case in point is the US grid – during 2021 the wholesale prices (5-minute intervals) turned negative about 200 million times across the seven transmission interconnection regions. A frequency distribution of such incidence of negative prices is the highest since 2016. By end of 2022, it could be even higher. It can thus be inferred that battery storage units' major application will be capacity deferral, adding to the other roles of grid management. In certain contexts, such energy storage application is also referred to as 'Storage as Transmission'.

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

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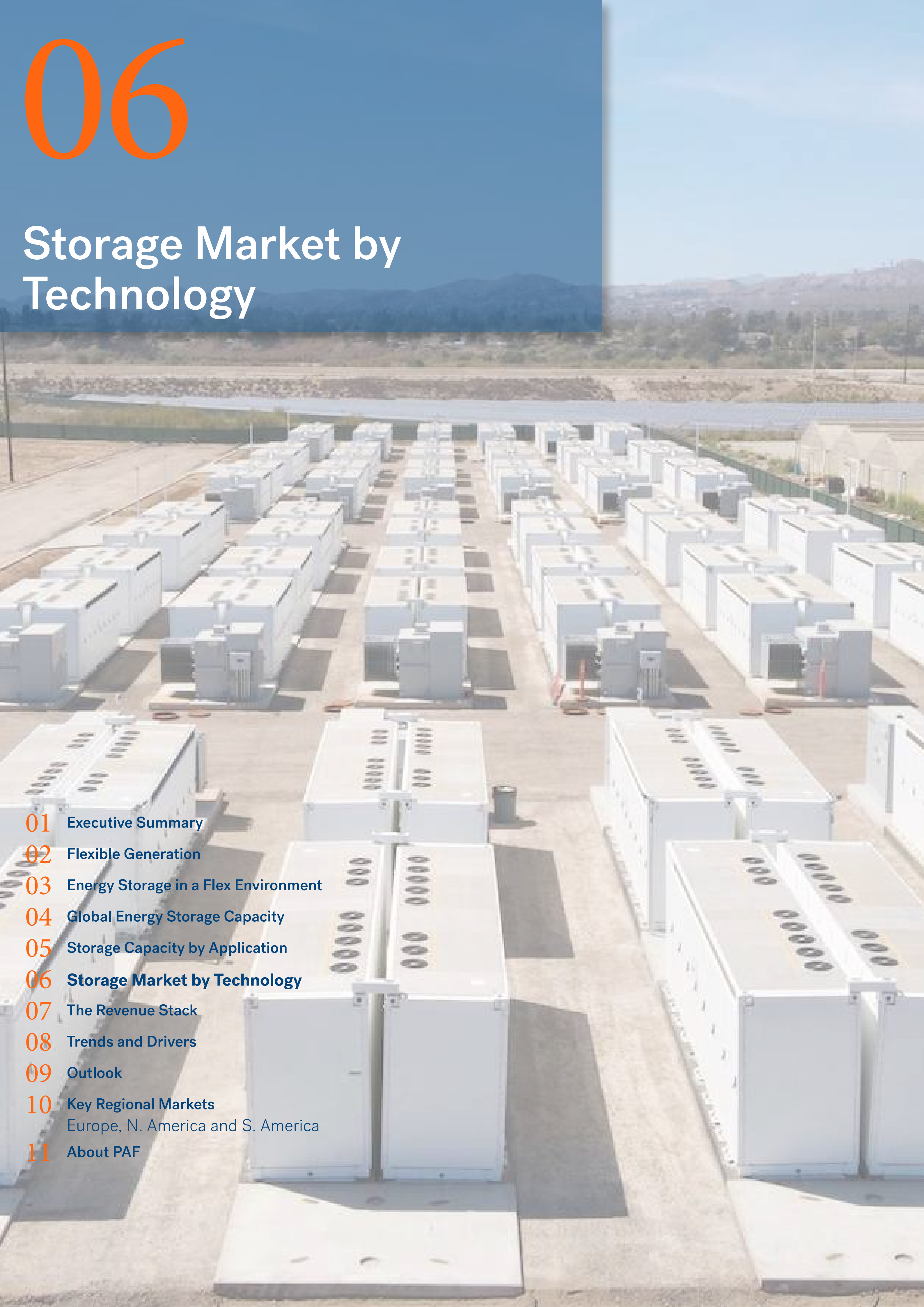
Storage Market by Technology



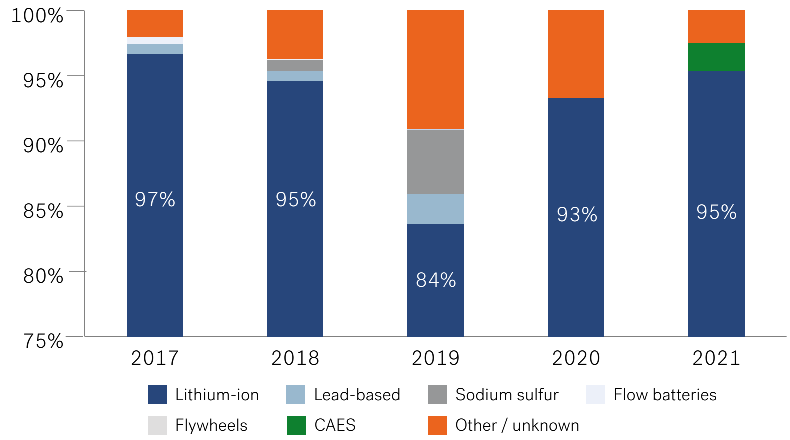
Storage Market by Technology

Pumped hydropower generation is the conventional, legacy storage technology that is ideally suited best for grid management and its related segments. The installed energy storage capacity is still skewed (about 83% share by end of 2021) in favour of the pumped hydropower stations. These are typical long-duration energy storage (LDES) assets in the grid (6-10 hours or more in storage/discharge) with long commercial life (25-30 years) and low average operational costs. Network operators continue to deploy pumped hydro capacities for its inherent advantages. Yet, this segment has stayed stagnant over the years.

Long gestation period, complex and lengthy environmental clearances and sensitivity to locations are the key points of disadvantages that progressively deterred investors from pumped hydropower plants. The pipeline has progressively shrunk as a result. It may however change with the rise in share of renewables. As LDES resources become critical for network reliability, network operators and developers may have to relook at pumped hydro. In 2021, Chinese State Grid Corporation started five pumped hydro stations and plans to enhance existing capacity from 26GW to 100GW by 2030.

Battery manufacturing ecosystem continues to be propelled by grid-scale storage and automotive powertrain

Trend in the Technology Mix of Commissioned Battery Storage Capacity



Source: BNEF

All the same, the focus is on the battery storage technologies impacting the global energy transition path. The reason is the commercialization and economies of scale in select major technologies such as Lithium-Ion, making it competitive choice for most developers. It also helps that the same electrochemical battery chemical formulation (as in Lithium Ferro Phosphate) has an even higher demand in the electric vehicles' segment. The battery manufacturing and its related ecosystem is thus propelled by the twin forces of grid-scale storage and automotive powertrain, the latter being the more significant one in demand-pull.

For long, multiple battery technologies are in consideration for competitive cost and performance to the Lithium-Ion. Recent developments indicate some progress in this regard. Sodium-ion batteries have lately emerged as among the leading options. The technology costs lower than Lithium-Ion due to easier access in its raw materials (sodium extracted from salt). At the same time these batteries are comparatively less in energy-density than their Lithium-Ion counterparts. This is partly mitigated by their lighter weight. The technology awaits further steps towards maturity and commercialization.

Storage Market by Technology

Lately, iron-based batteries constitute another set of emerging storage technologies that developers are taking up for standalone grid-scale deployment. In 2021, ESS launched its iron-based battery offering 4-12 hours' worth of storage. Another company Form Energy is planning a similar battery-based pilot plant worth 1MW by 2023. Due to the cost-effective raw material (iron), the batteries promise a far lower cost than other options in the market. Yet, this technology too is subject to limitations that yet to be worked around. One is its lower efficiency. Others include unwanted side reactions that could potential degrade the performance levels.

Investor interest will play a crucial role in the development of advanced battery technologies

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)

All technologies carry varied trade-offs in costs and performance that can be resolved, not just with the additional doses of R&D investments but also with commercial scale. Some of the advanced battery technologies could therefore be implemented at a larger scale as investors seek a toehold in the emerging electrification of power and transport networks.

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

Note: (a) Asset availability is based on UK's capacity market auction de-rating factors

(b) synchronous generation also provides reactive power and short-circuit along with inertia

(c) Pumped hydro, among long-duration storage sources, is a mature technology. But it is constrained by location and development costs.

Storage Market by Technology

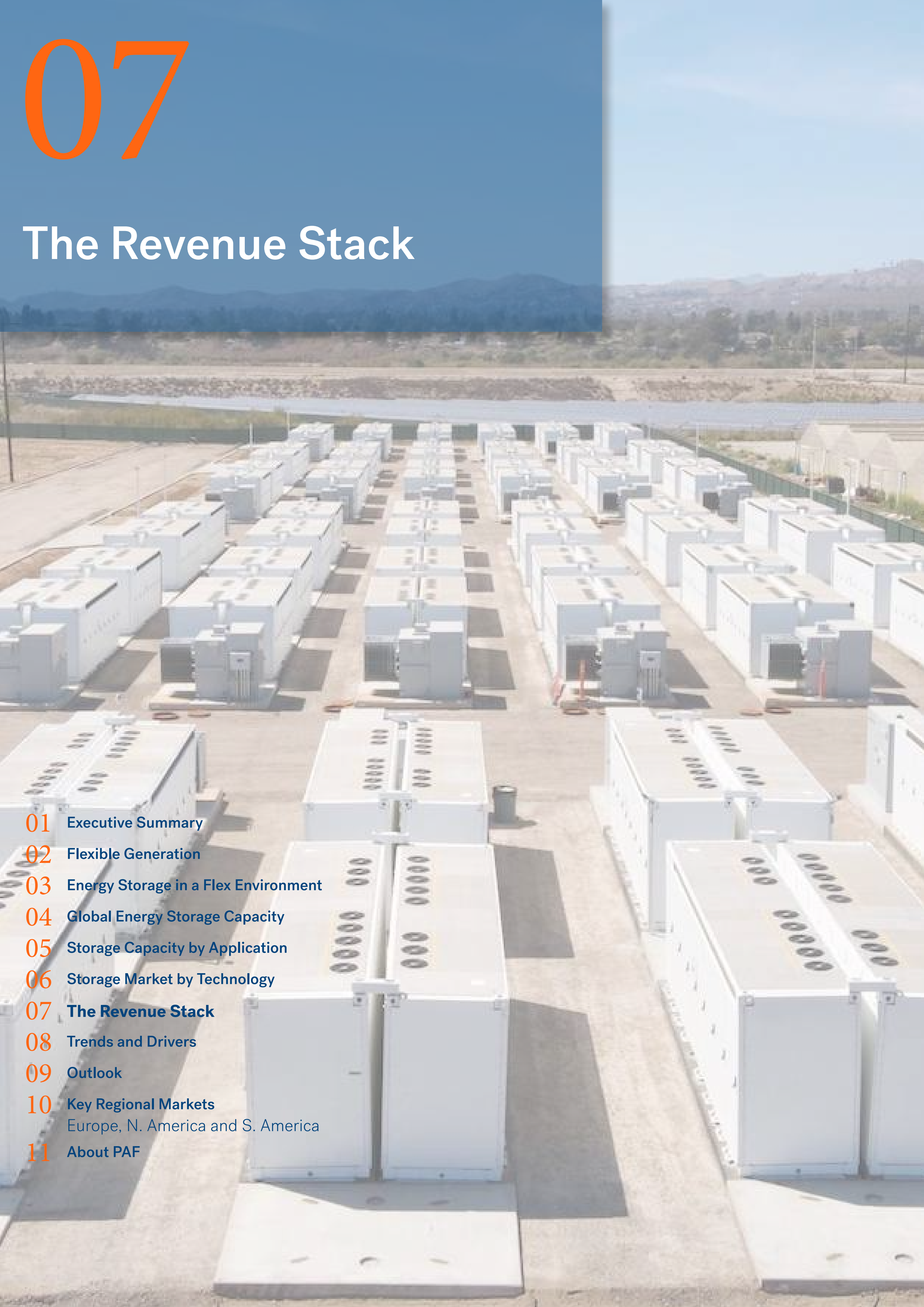
LDES is an emerging priority area for both regulators and the network operators, as supply reliability and stability becomes a challenge in the energy mix. For practically all the existing commercially viable options, LDES remains an elusive one. This is either due to the costs involved (in prevailing incentive structure of the power markets) or the technical performance falling short of requirements.

Quite a few are in a testing phase through pilot or demonstration projects. For instance, thermal storage (based on molten salt) is an established technology in terms of the requirements involved. A 100MW pilot is underway in China. Also important is the Compressed Air Energy Storage (CAES), that stands out for the longer life and well-developed technical base for the components involved. In October 2022, the Chinese Academy of Sciences commissioned a 100MW CAES plant, regarded as the world's largest existing storage plant based on the technology. In July 2022, the company Poland Night Energy commissioned Finland's first sand-based thermal energy storage system. It is an 8MWh system (to be scaled up in future), meant for the energy requirement of the local district heating system. The multiple LDES technologies currently under development fulfill certain niche requirements. The falling costs of such technologies could help the segment emerge with 1-2 preferred and established choice of storage form.

LDES will prove to be an emerging priority area for both regulators and network operators

07

The Revenue Stack



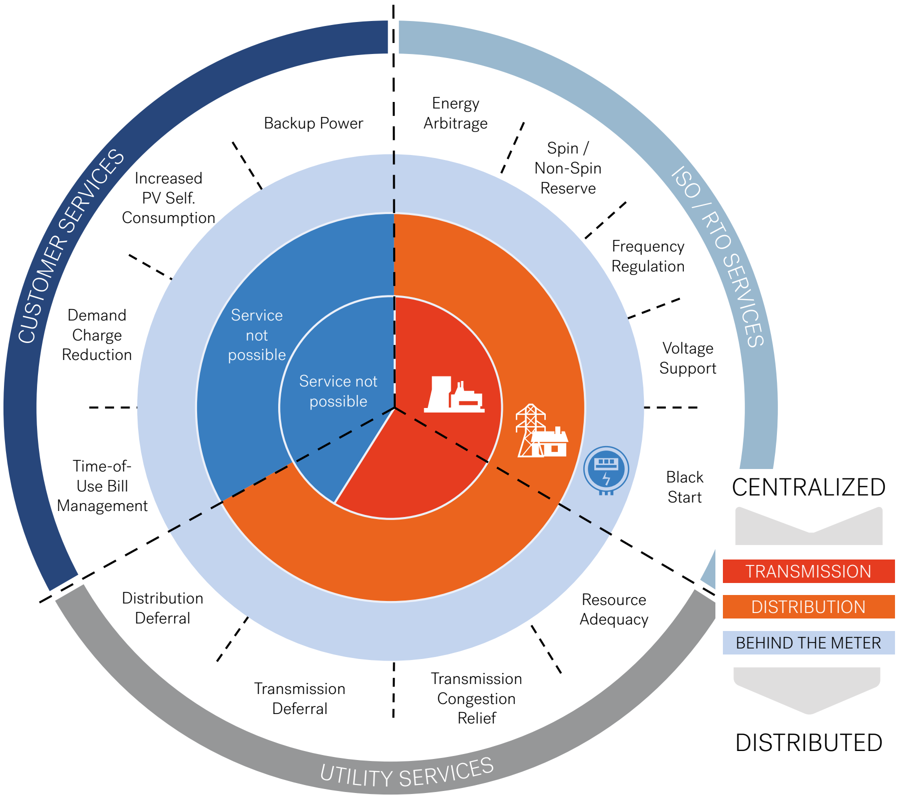
The Revenue Stack

By their inherent nature, battery storage systems are capable to serve different markets segments based on the same capacity and configuration. The assets are thus most economical and viable only when the multiple service opportunities are monetized. But most of the countries are found wanting on exactly this part. This is largely due to the lack of appropriate regulatory norms needed for batteries to participate in the bulk power markets (short-term and long-term) along with incumbent generation resources (primarily conventional energy).

With an expanding and gradually maturing energy storage market (though skewed), the issue of revenue stacking (also referred to as value stacking) is gaining currency among policy and regulatory authorities. It is only by the right design of incentive structure can the market expect a wider participation of standalone battery storage developers. The California regulators, for instance, were the first in the US market to allow multiple revenue streams for battery storage systems. In 2018, the California Public Utilities Commission approved new market rules for the energy storage systems, for resources to stack incremental value through services in the wholesale power market, distribution grid, transmission system and others.

Updated incentive structure can facilitate a wider participation of standalone battery storage developers

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



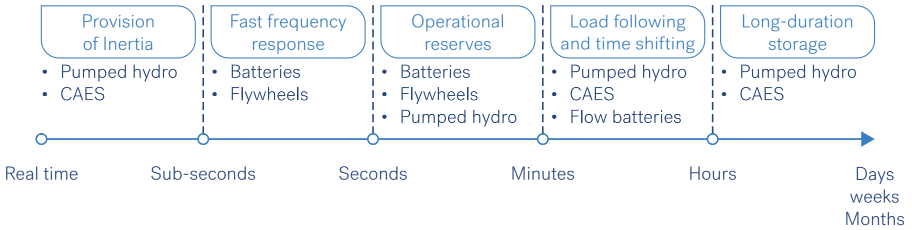
Source: Rocky Mountain Institute

The Revenue Stack

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. For instance, 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.

Fixed price contracts continue to be the preferred revenue generation model

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. The resulting estimates on income streams often set the basis for seeking project financing. 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. In the US market, fixed-price contracts take the form of tolling contracts (or capacity contracts) entailing the payment for battery capacity for availing right to dispatch energy from that system subject to the regulations and procedures. 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.

The Revenue Stack

In California's utility-scale projects, the energy storage contracts include a fixed-price payment for the resource adequacy attributes. Utilities and other power supply entities in the state are required to procure power for resource adequacy as a contingency to meet customer demand. Such projects can sell the power to the same buyer of the resource adequacy attributes or can supply it to another buyer.

Storage facilities paired with the renewable energy generation projects (wind and solar) are able to 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 power purchase agreements. 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. This is observed in California where industrial consumers incur high demand charges based on the applicable time-of-use tariffs.

In addition to the capacity or energy service contracts, the storage developers offer ancillary services to the transmission service operators. Such services take varied forms, depending on the nature of the grid operations and the specific operator requirements. 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 tariff schedule or project owner's.

Co-located storage facilities projects facilitate a mix of fixed and variable revenue sources

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 underly-ing the project	Low Revenue stream is merchant-based, vary-ing hourly or yearly

Source: Sterlite Power

08

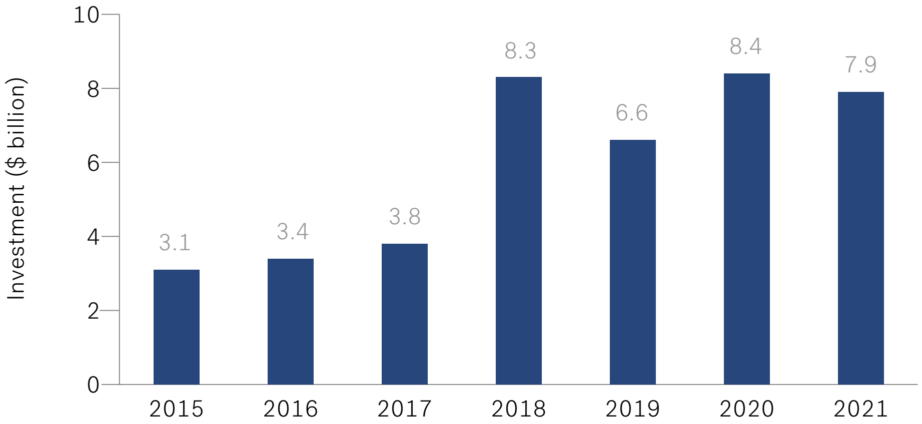
Trends and Drivers

Trends and Drivers

The energy storage market increasingly finds a greater investor interest for the solutions on offer. This is 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. Further, with an evolving technology landscape in this industry, the investment flow is progressively directed at the major storage technology configurations showing promise for commercialization.

Investments towards energy storage projects jumped from an average $3.5 billion during 2015-2017 to roughly $8 billion during 2017-2021

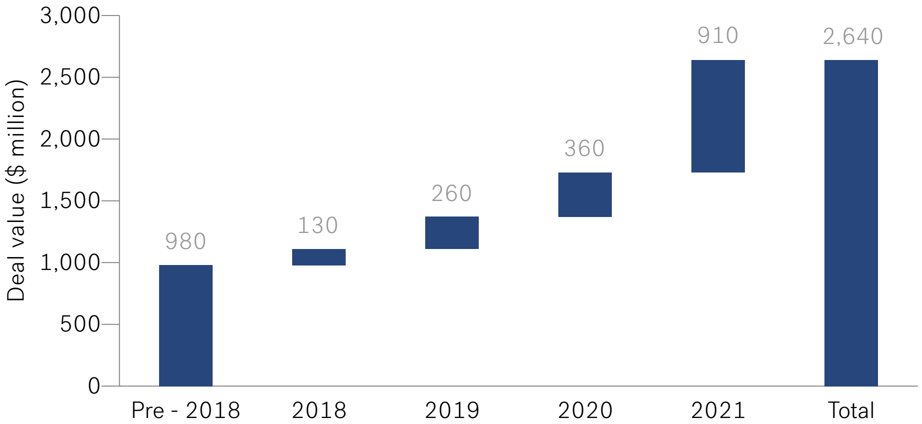
Investment Commitment towards Energy Storage Technologies



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. Most of these are part of the overall energy transition spending underway across multiple projects. A predominant share of utility-scale battery storage projects in the US, for instance, are those paired with a renewable energy project. Investors at the same time, are also extending commitments to the promising enterprises entering the markets as standalone energy storage service providers. The investment scope remains untapped as yet, as many of the 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

Trends and Drivers

The rising need and criticality of the LDES technologies propelled investors interest in the space. As per McKinsey estimates, over 260 LDES projects have been announced worldwide, and are at different stages of commercialization. Majority of such capacity is based on traditional molten salts (typically used in the concentrated solar plants storage) and compressed air energy storage systems. Thermal LDES holds the maximum share in the current technologies under testing or development.

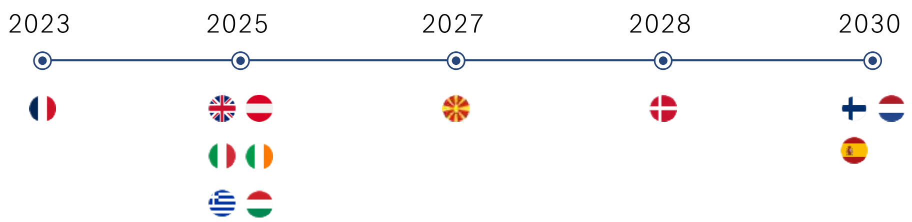
Planned phase out of coal-based power generation accelerating across countries

Displacement of Conventional Energy in Grid

The planned phase out of coal-based power generation capacities appears to have taken traction across the countries. In May 2022, the top government representatives from the G-7 industrial countries placed their commitment to stall government financing for international coal-fired power generation and to accelerate the phasing out of unabated coal plants (those which do not have carbon capture technology) by the end of 2035. The formal commitment thus made, marked a discernible shift in the general policy perception towards coal-based power that otherwise continues to be the bedrock of power systems in many countries, not only for China and India (leading coal consumers) but also for Japan (part of G-7).

The countries in European region have formalized individual timelines to phase out coal-based power. A few such as Portugal, Sweden and Belgium have completely shut down coal-based power in their energy mix. Others have announced tentative timelines. The energy crunch (primarily in natural gas) imposed by the Russia-Ukraine armed conflict could temporarily force a change in plans. France and Austria are two such examples. Both had advanced their dates to close the coal-fired plants, but have since mulled reopening them to bridge the energy shortage. The direction however remains clear. Paris Agreement's stipulations entail closing all coal-based generation by 2030. European countries not aligned to the 2030 target are making progress too. In October 2022, Germany's biggest power utility RWE announced closing of its coal-based power plants by 2030 – advancing its plans by eight years.

Tentative Coal-based Power Phaseout Timeline in Select European Countries



Note: Some of the above countries announced advancing of targets but have also reopened coal-based power to address demand

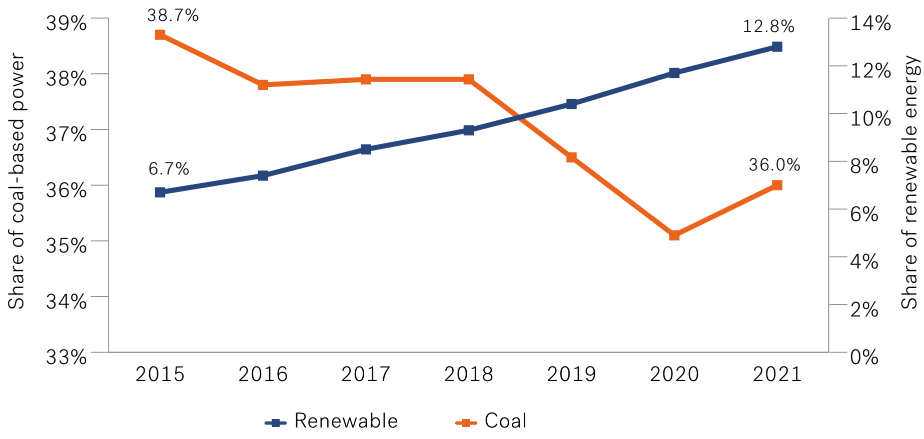
Source: Europe Beyond coal

Trends and Drivers

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. The implications of removing such power generation are onerous for network operators. Closing coal-based power removes the baseload, dispatchable source of energy that is useful to balance against and integrate intermittent generation resources. It is likely that the solutions will have to be found in terms of alternate generation such as in gas that has lower emissions and properties of grid stability.

IEA expects energy sector infrastructure & related technologies investment to rise to about $4 trillion by 2030

Relative Share of Coal and Renewable-based Power Generation



Source: BP Energy Statistics, 2022

Requirement of Grid Upgrades and Modernization

The rapid and drastic energy transition underway imposes significant requirements on the existing power transmission infrastructure. With rapid generation capacity addition, grid connectivity becomes a critical and often a bottleneck for developers. Also, with rise in distributed energy generation resources, it might be challenging 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. The delays in such investments carry a huge opportunity cost – delaying or cancelling future project prospects. An illustration of such a scenario is seen in the transmission congestion at the US network operator regions. During 2019 – 2021, the ISOs' transmission congestion costs rose from $2.7 billion to $7.2 billion. There is thus an urgency to address the infrastructure gap.

In 2022, the US Department of Energy launched the 'Building a Better Grid' initiative, involving an outlay of $12.5 billion (allocated under Infrastructure Investment and Jobs Act) 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. At the same time, the ISOs are building up their own plans to address the issue. MISO for instance announced a $10.3 billion worth of major transmission upgrade.

Increasingly, interconnectors are emerging as one of the counterbalancing factors in ensuring a flexible power system. In Australia for instance, a $2.6 billion worth of HVDC line is under development to connect a renewable-rich island (Tasmania) with the Australian mainland. The EU has the most significant project pipeline in this regard. Increasingly, interconnectors are coming up in the European region as a standalone business through project financing. An example in point is the Greenlink interconnector aimed at linking the UK and Ireland power systems by 2024. It is the first privately-financed interconnector project in the European region.

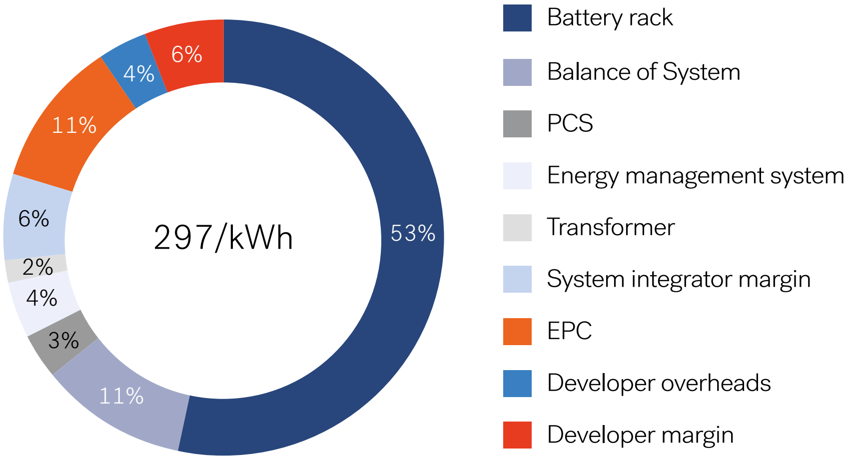
Trends and Drivers

Battery Supply and Costs

The rapid decline in the battery costs is the most important factor 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. The costs are expected to be rationalized with lower battery costs, changes in system design, standardization in the duration systems on offer and the overall maturity of the storage market.

BNEF estimates indicate average cost of a four-hour utility-scale battery storage system to reach $167/kWh by 2030

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

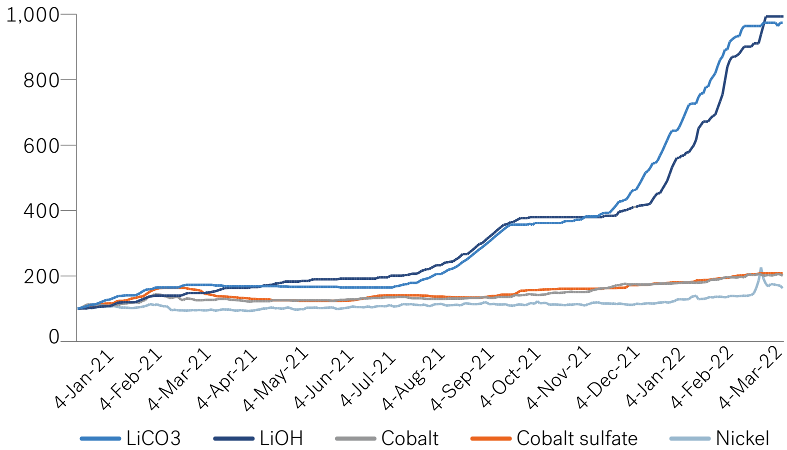


Source: BNEF

The projections around rationalization of the battery costs (based on Lithium and others) could however be tempered by the global inflationary pressure. Lately, many storage developers have been forced to re-negotiate the prices or postpone capacity deployment.

Significant pressure comes from the electric vehicle demand segment that has a far bigger share in sourcing batteries than the power sector presently. An example in point are the contracts signed at California's Central Coast Community Energy, where the developers sought renegotiation due to the rise in battery costs for projects nearing completion dates. As a contrasting example – developers in Hawaii and New Mexico states of the US scrapped the projects due to erosion of the returns. A mitigating factor could be the global recessionary expectation – commodity prices may ease downwards in case of an anticipated slowdown in the markets.

Battery Metal Price Rise Between January 2021 and March 2022



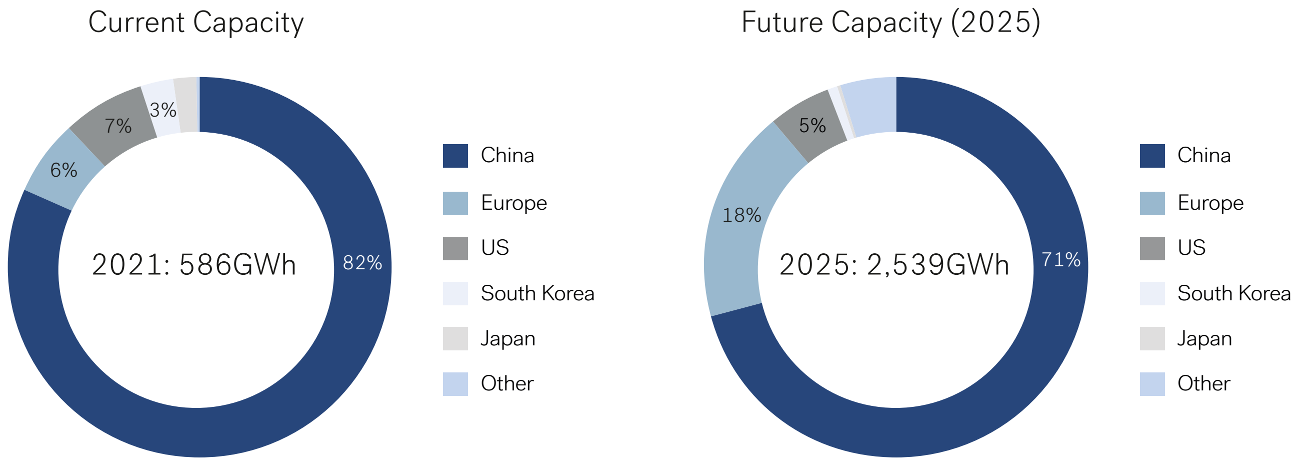
Source: BNEF

Trends and Drivers

The predominance of the Lithium-Ion technology in battery storage installations is largely unchallenged in the market. With multiple demand segments for this technology, manufacturing capacities have been expanding rapidly, thus contributing to the outlook on further cost reductions. Till recently the battery manufacturing and related supply for energy storage units was largely geared around the supply meant for the electric vehicle industry. This is gradually changing, with several manufacturing units developing and supplying components specific to the energy storage developers' requirements.

Urgent need for a diversified supply chain and reduced reliance on select countries

Lithium Cell Manufacturing Capacity by Plant Location Region



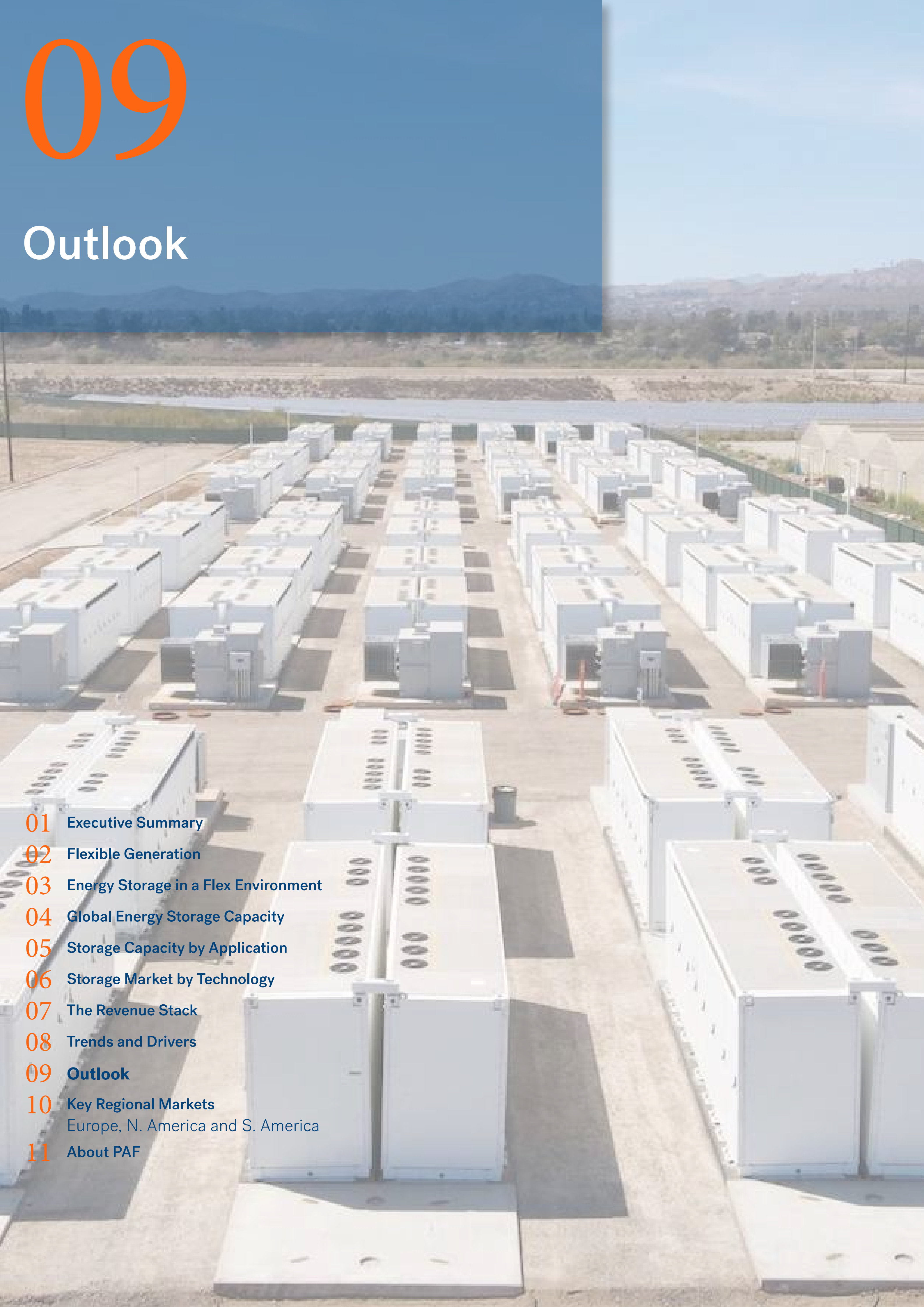
Source: BNEF

One striking element of the upcoming manufacturing capacity is the diversification of base underway. While China's market dominance is a given, the European region is poised to massively enhance its indigenous production base. Over 38 Gigafactories are planned in the region – the latest being Tesla's commissioned at Berlin, Germany in March 2022. In the last two years, battery production capacity tripled in Europe. 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.

Among other technologies, lately, sodium-ion batteries have come to the forefront in mass production and commercialization. Some of the leading manufacturers such as CATL are in the process of developing these batteries at scale. Importantly, the cell production and component material processing for sodium-ion batteries is similar to those of Lithium-Ion. Thus, the existing infrastructure and supply linkages for Lithium-Ion batteries could be leveraged for the production processes of sodium-ion. Progressively, the rising battery metal prices and the cost of Lithium could strengthen the case for sodium-ion batteries. It also helps that such batteries do not face the same challenges of raw material sourcing and costs as the Lithium-Ion and others.

09

Outlook



Outlook

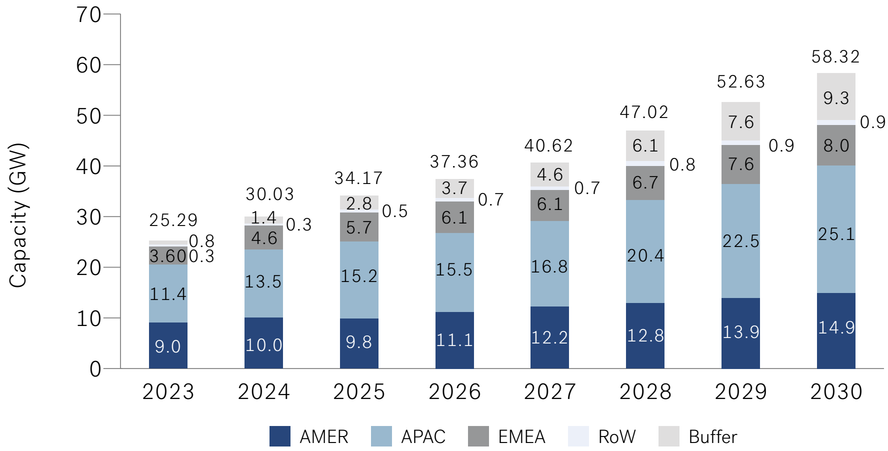
The bullish outlook on energy storage market reflects the strength of underlying factors driving the market – renewable energy penetration, rapid decline in battery costs, and the regulatory changes in the power markets. The project pipelines and the new technologies under consideration indicate a wide scope of the projected opportunity. Yet, the growth in near to medium-term could be concentrated in a handful of the countries due to the maturity and scale of the power sector. Added uncertainties in the picture could be from the supply chain issues due to the continued pressure on logistics at China and the Russia-Ukraine armed conflict impacting global economy. At the same time, 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.

BNEF projections indicate a five-fold rise in the annual battery storage installations by 2030, compared to 2021

Storage Capacity Growth

BNEF projections indicate a five-fold rise in the annual battery storage installations by 2030, compared to what was installed in 2021. The quantum of growth, in terms of power capacity (GW) is reinforced by the fact that a rising number of markets are adding grid-scale storage units. These typically entail higher unit sizes than the off-grid or behind-the-meter ones. Rising deployment for grid management roles is likely to involve a greater dose of capacities in the respective markets.

Projected Global Annual Battery Storage Installation



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

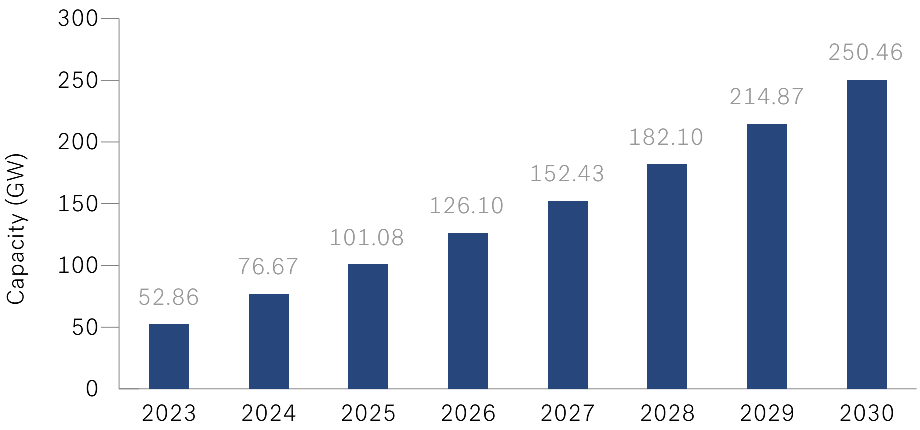
US and China drive the bulk of storage capacity growth during the forecasted period. Also, while the US storage market is the world's largest, estimates indicate that China's market could surpass and take the top position by 2025. China's targeted 30GW energy storage makes it a very important market for all the stakeholders to pay attention. The US market meanwhile is characterized by an expanding project pipeline of utility-scale projects which are predominantly hybrid projects (storage-linked renewable energy). The states/regions of California, Texas and Southwest hold a disproportionate share of the US battery storage project pipeline.

Outlook

The capacity growth momentum is relatively muted in the Europe, Middle East and African (EMEA) region. In the European markets such as Germany, Italy and Belgium, the storage growth has been picking up. Yet the European countries' deployment of transmission interconnector capacities tends to offset the scope of storage capacities. Instead of utility-scale, it is the residential storage segment that holds the sway in the European market growth. In the aftermath of Russia-Ukraine conflict, the emphasis on energy security has brought the focus back on utility-scale storage projects (to support renewable energy in the grid).

Revenue model of the large-scale batteries continues to be constrained

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. The linear growth projections across most of the industry studies may be subject to riders. The regulatory frameworks, even in the leading and mature markets, are behind the curve. The revenue model of the large-scale batteries thus continues to be a constrained one. For the most part, developers will thus frequently be working under a constraint wherein the capacity is able to service multiple revenue streams, yet the monetization occurs for only one or few of them.

Costs could be an important factor to contend with in the projected utility-scale segment growth. Despite the decline in costs so far, the storage costs need to be rationalized further for better commercials in the power mix. Achieving lower costs could become progressively difficult for the Lithium-Ion technology in its existing configuration. Meanwhile the global inflationary pressures and rise in commodity prices have already impacted many of the energy storage projects.

Outlook

Changing Application Mix of Storage Capacity

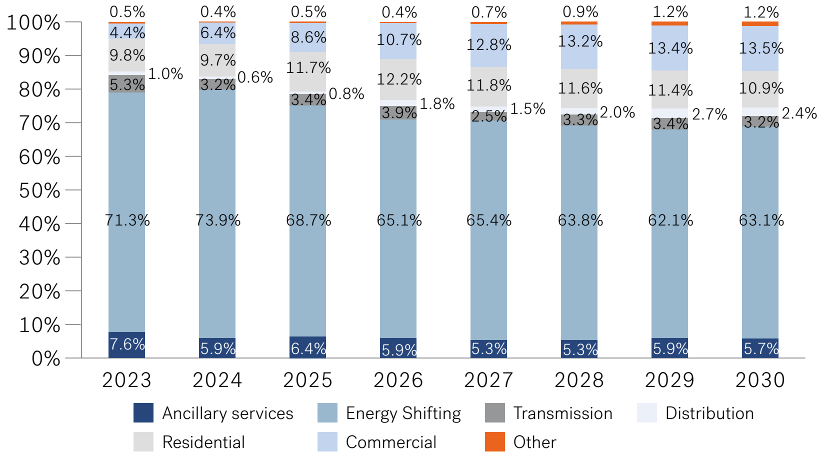
Energy arbitrage (or energy shifting) is already the dominant use of battery storage assets. About 60% of the storage capacity addition by the end of 2022 is expected to be devoted to the arbitrage role. It is the case in leading storage markets of US and China, where arbitrage along with renewable energy support and grid reliability is the leading role of deployment. Progressively other markets such as the UK and India are expected to enter the fray, with addition of storage capacity in the energy arbitrage roles.

It should however be noted that the ancillary services' share in the overall battery storage market revenue could experience a fall. BNEF estimates point to 15% of total battery storage deployments directed at the ancillary services. A significant share of momentum comes from the rapid market entry by developers in the US (specific markets such as Texas) and the UK to take an early advantage of the emerging merchant-based ancillary services market. The high deployment rate for ancillary services may not sustain over time. With more storage capacities in the market, the commensurate moderation in prices of ancillary services could reset the market closer to the fundamental equilibrium level.

The residential and commercial storage installations are projected to rise in importance. This will be led by favourable policies in rooftop solar, especially in the countries including Germany, Australia, Japan and select states in the US. Also important is the gradual phasing out of the provision of net metering by many regulators across the world. Energy storage becomes relevant in the absence of net metering for the solar installations in residential applications.

BNEF estimates point to 15% of total battery storage deployments directed at ancillary services

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

Outlook

Emerging role of Long Duration Storage

Technology deployment at scale, starting with select implementation in niche segments/markets will be helpful in ensuring discovery of opportunities. An example in point is the provision of grid inertia services. As of July 2022, South Australia's 150MW Hornsdale Power Reserve (also referred to as Tesla Big Battery) launched inertia services for the Australia's National Electricity Market. This came after two years of trials and the battery project is regarded as the first such grid-scale battery unit to provide inertia. The fitment of the service is appropriate – the region has had renewable energy penetration reach 64% and services for grid stability are critical. It is expected that such a commercial service use-case could help establish the technology configuration for subsequent deployment.

The technology landscape in the energy storage will be keenly watched for the segment in long duration energy storage (LDES). The existing commercially available battery storage options are limited to the less than 4 hours' segment. The energy transition and the demands on system flexibility make LDES a critical resource for the grid operators. There is a select set of 7-8 technologies that appear to be leading the race in contention of LDES deployment. A few are already operational but are constrained by limitations in location or deployment (such as pumped hydro storage or concentrated solar plants' molten salt storage).

While the commercial deployment remains far, the select set of leading technologies are likely to receive greater funding support and development to attain the LDES solutions. Most of them are expected to be aligned to the capacity market demand fulfillment. Yet, it is the ancillary services' function where most of the value proposition lies. Large-scale commercial deployment is important to ensure rationalization in the costs through economies of scale. As per McKinsey's report on LDES (as of November 2021), by 2040 investments in this technology segment could reach $3 trillion.

McKinsey predicts LDES investments to reach $3 trillion by 2040

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, re-serve, 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

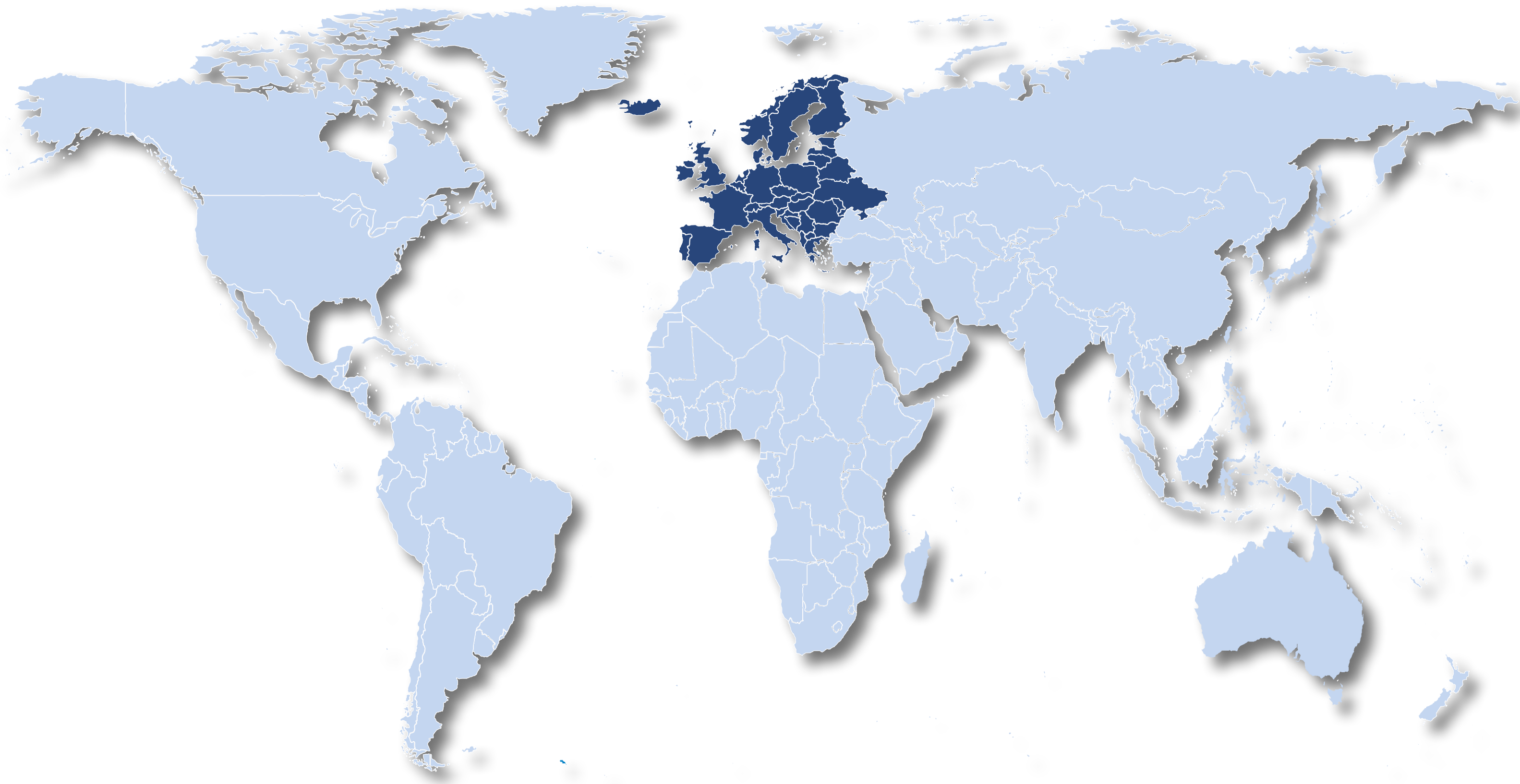
Note: 1) Short duration Li batteries are market ready, long duration is not yet seen to be established in the market; 2) Suitable power conditioning system required; 3) Molten salt refers to concentrated solar power with storage; 4) Hydrogen-to power refers to CCGT only; 5) Under operating cost category,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

Source: Aurora Energy Research

10

Key Regional Markets

Key Regional Markets - Europe

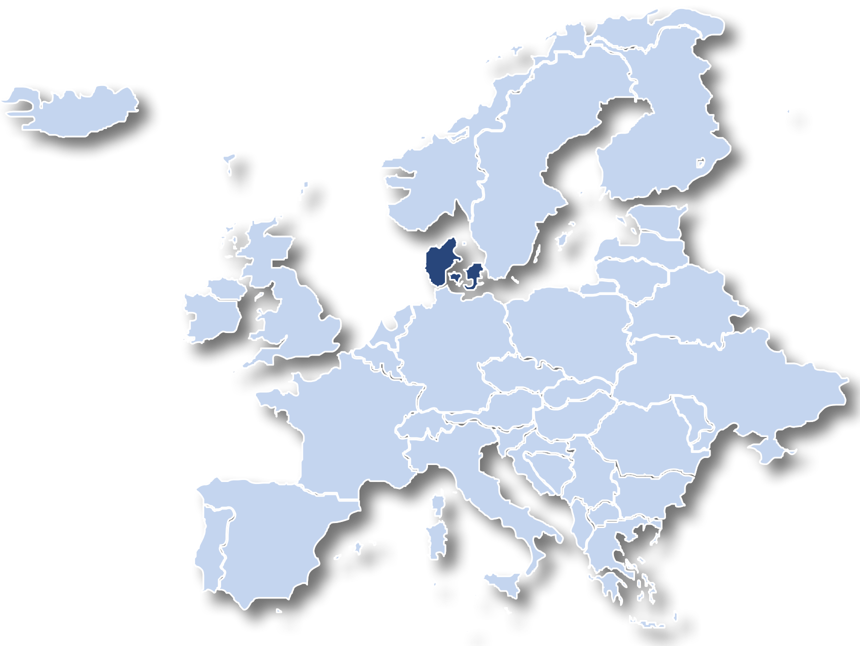


Denmark

Denmark stands out among European countries for successfully transitioning to a renewable energy-led power system. The country's renewable capacity growth is primarily based on wind power projects. The energy system is thus poised to achieve a position of running without conventional energy by 2030. At the same time, the power network remains as robust as any of its regional counterparts. Strikingly, energy storage technologies are yet to play any significant role in the Danish power system. Part of this stems from the country's power market structure and integration with the larger Nordic and European markets.

GDP (Current Prices) USD (2021)	398.30bn
GDP Growth Forecast (constant prices) (2022-2026)	1.74%
Currency	Danish Krone
Country Credit Rating (S&P)	AAA
Energy Storage Capacity* 2021	2.3MW
Renewable Energy Share 2021	61%
Energy Storage Outlook 2030	-

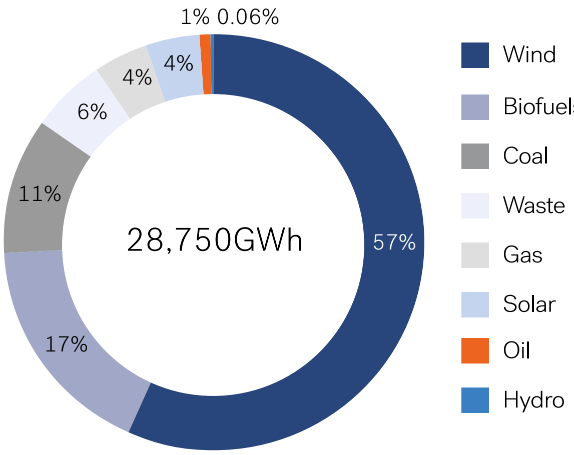
GDP Source: IMF WEO, S&P and IRENA
*Excluding Pumped Hydro



Denmark

Energy Mix and Case for Storage

Electricity Generation by Fuel Type (2020)



Source: IEA

Denmark's power sector is skewed towards renewable energy, led by wind power generation. The energy transition is a key focus area in government policy, where the long-term objective is to achieve net-zero emissions by 2050. To this end, several measures are targeted in the interim. For instance, coal-fired generation is slated for phase-out by 2030. The electricity supply will be aligned to renewable energy sources by the same timeline. In June 2022, an agreement was signed in the Danish Parliament to affirm a targeted quadrupling of onshore wind and solar and quintupling of offshore wind power by 2030.

The Danish electricity system's high renewable energy penetration has not dented the network's reliability. It continues to maintain system performance levels comparable to the other networks in the region. One of the significant factors contributing to this is the network operator's (Energinet) cross-border interconnector infrastructure connecting Denmark to the Nordic and Central European power trading systems. The cross-border power market exchange is an integral part of maintaining balance. Together with this, the appropriate power market design is instrumental in ensuring that capacities operate flexibly as much as feasible.

Against this backdrop, the role of energy storage has been negligible. While the network operator recognises the role of storage technologies, the fitment is yet to be worked out. Most importantly, grid management continues to be addressed within the existing power market framework.

Capacity: Status and Trend

As per BNEF's tracked data, Denmark had about 2.3MW worth of battery-based energy storage capacity. The installed capacity includes technology testing or demonstration projects to establish commercial viability. More standalone storage units are gradually coming up, though at a much slower rate. In September 2022, a 2.3MWh battery storage unit was set up by Vestas, operating for now as a proof-of-concept. This is the country's largest standalone battery storage project so far. It is utillised as a charging station for electric vehicles, drawing main power from connected wind generation. Battery storage technologies are the only feasible option in the Danish system, considering the absence of pumped hydropower generation capacities.

Denmark's Energy Storage Assets (as of 2021)

Project	Application	Technology	Year of Commissioning	Capacity (MW)
Radius Nordhavn Energy Storage	Short duration balancing	Lithium-ion	2017	0.32
Radius Nordhavn Energy Storage	Technology testing	Lithium-ion	2017	0.32
Vestas Denmark Energy Storage Pilot Project	End-user services - Other	Lithium-ion	2013	0.60
Vestas Denmark Energy Storage Pilot Project	Renewables integration	Lithium-ion	2013	0.60
A123 Systems Denmark Energy Storage	Technology testing	Lithium-ion	2013	0.40
Riso National Laboratory Roskilde Energy Project	Technology testing	Flow	2006	0.15

Source: BNEF

Denmark

Policy and Regulation

The Danish TSO Energinet devises the norms and practices related to grid management and the related services that are potentially relevant to energy storage. The TSO relies significantly on the interconnector network instrumental for cross-border transactions. From a grid management perspective, the interconnectors enable network congestion management, capacity markets, and ancillary service markets to ensure seamless integration.

About 2MW of energy storage capacity is requisitioned in Energinet's grid ancillary service requirements (estimate as of end-2020). Battery storage systems are part of the approved generation systems for the reserve power and balance energy markets framework. In compliance with European regulatory practice, all battery storage capacities are more likely to be owned by third-party due to restrictions on TSOs from engaging in market operations from owned capacities.

Energinet's study commissioned for the feasibility of engaging energy storage systems Danish network points to the limited value in the existing power market framework. It is only in the ancillary services segment where the storage assets can be expected to have a greater scope to participate in the coming years.

Market Developments and Opportunity

The Danish market is yet to be effectively tapped for battery storage in grid management. The opportunity is expected to unfold as the power system expands while phasing out all operational thermal capacities.

Energinet's study in this context, as referred to earlier, has some pointers. The ancillary services segment is one. Battery storage technologies satisfy the market's technical requirements and can accommodate the demand related to primary and secondary reserves in the frequency response market. In the analysis done, the Danish primary frequency reserve was found to offer attractive returns on investments for a potential future rollout.

More demonstration projects are underway to establish the business case in the upcoming grid scenario. The Bornholm Smartgrid Secured System (BOSS) is one grid-scale storage demonstration project operational since 2021. This 1,110kW, DKK30 million project was co-funded by the Danish Energy Technology Development and Demonstration Program. The BOSS project partners are ready to expand the testing and experimentation for various grid services and use cases. Bornholm is one of the two islands tentatively marked for setting up as hubs collecting offshore wind energy generation to route it further to Danish and other neighbouring European power transmission networks. The Bornholm Island will have an estimated 2GW capacity for power transfer.

An important demonstration project conducted in 2020, jointly by Energinet and Energi Danmark (energy trading company), sought to explore the possibility of a wind power project in a grid balancing mechanism or ancillary service segment. The project concluded that with forecasting precision, wind power projects could participate in the market for balancing services. With further investments, this could be scaled up for opportunities to pair wind power plants with storage facilities to fetch higher value in the grid balancing services market.

Outlook

The future rationalisation of the costs of battery storage systems and the commercialisation of better technical configurations could change the existing paradigm. Some of the technologies under testing hold promise in this context. Furthermore, the Danish power system is likely to rely on interconnectors to ensure the system's reliability and balance till battery storage systems offer a competitive and efficient alternative for the network operator.

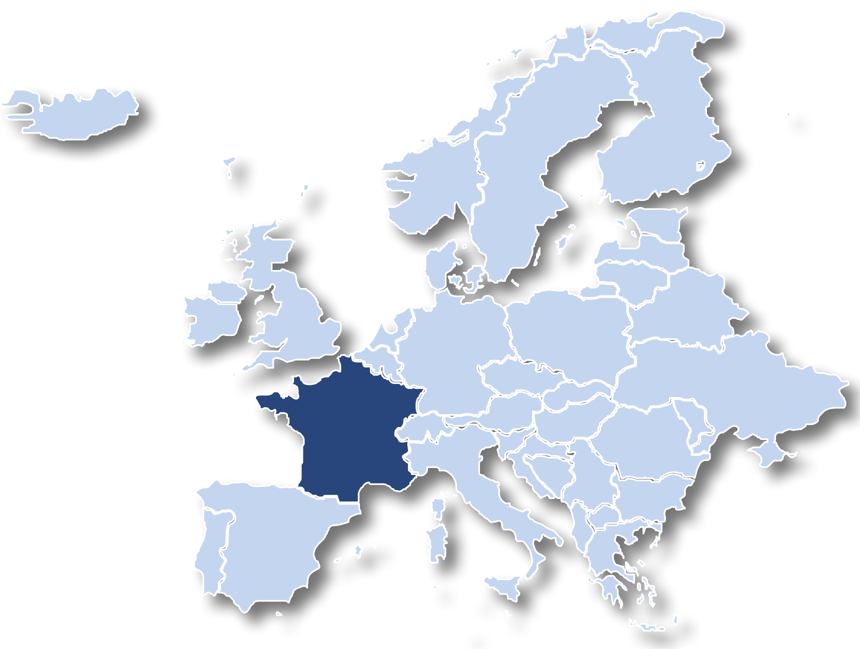
The Danish energy storage market carries significant potential with a conducive market design. It is now at a nascent stage for battery storage developers. There is limited scope in value-stacking, and the lack of incentives against existing market mechanisms with Nordic countries deters potential large-scale investment. Yet, the ongoing energy transition, the battery storage demonstration projects, and the planned rapid scaling up of wind power capacity could collectively shape the outlook for the better.

France

The French energy storage market is gradually emerging to play an integral and vital role in the power mix as the country undertakes a transition to greater renewable energy generation in the overall power supply. To be sure, the capacity is developing and slowly coming up to the demand prospects. Grid-scale energy storage is the focus area of growth, while residential / distributed storage is yet to pick up on a significant scale. Policy and regulatory framework in this context have an essential role, as indicated in the recent auctions and other capacity allocations.

GDP (Current Prices) USD (2021)	2,957.43bn
GDP Growth Forecast (constant prices) (2022-2026)	1.64%
Currency	EURO
Country Credit Rating (S&P)	AA
Energy Storage Capacity* 2021	295.91MW
Renewable Energy Share 2021	22%
Energy Storage Outlook 2030	2,029MW

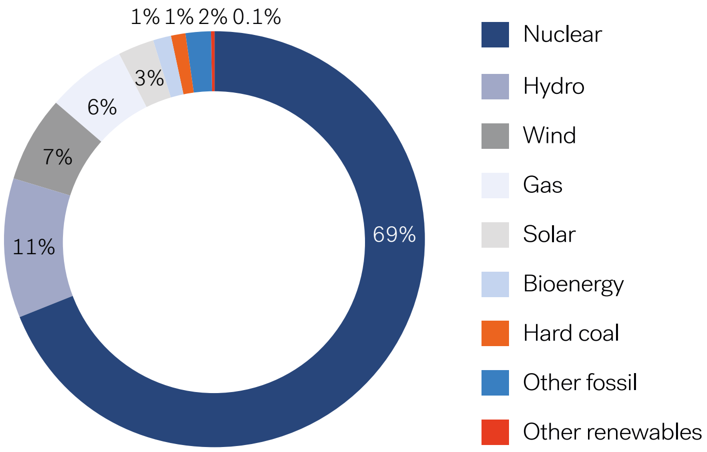
GDP Source: IMF WEO, S&P and IRENA
*Excluding Pumped Hydro



France

Energy Mix and Case for Storage

Electricity Generation by Fuel Type (2021)



Source: Statista

Nuclear power generation has the predominant share in the French power mix. From the grid operator's perspective, nuclear power generation fits the requirement as a competitive baseload option. Renewable energy, in contrast, has yet to pick up in the country, presenting a contrasting picture to its other major European Union counterparts. The presence of hydro and nuclear power has also kept the power sector's emissions significantly lower, thus exerting relatively lower pressure to transition to renewable energy.

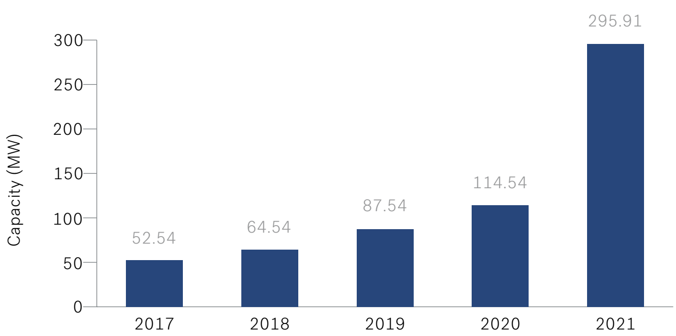
However, the trend is gradually shifting as the regulatory framework is seeking a time-bound transition to renewable energy, keeping with the European targets. France has lagged in meeting renewable targets. It is gradually changing with auctions for renewable energy and a planned phaseout of conventional power generation capacities. Thus, progressing the requirement to place adequate flexible generation capacities in the network to enable the impending transition. Therefore, the demand drivers for energy storage are two-fold – comprising both renewable energy integration and the gap arising from phasing out of the conventional but dispatchable power generation capacities.

Capacity: Status and Trend

The French energy storage capacity growth has been muted in contrast to its major European counterparts. Yet, the priorities appear to be shifting gradually. Stationary storage capacity (non-hydro) rose by over 2.5 times in 2022 over the previous year's level. For the preceding three years till 2020, the average annual growth in such capacity was just about 30%. The storage capacity jump reflects the changing systemic requirements in the energy mix.

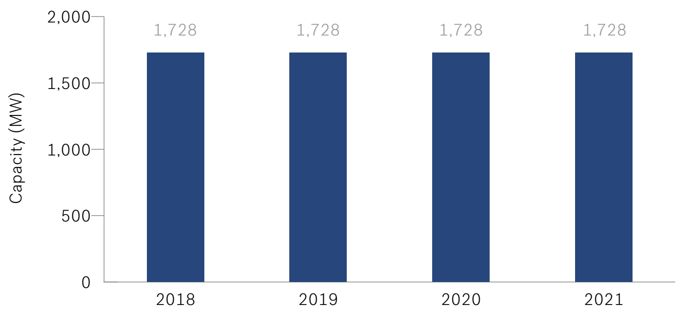
Utility-scale storage is a predominant factor in the country's existing storage market – marking another distinction from other key European markets like Germany or Spain, where the residential segment is the growth driver (due to solar power). Yet the growth is picking up rapidly from the low base – from just no capacity in 2017 to 29MW. The demand driver, however, is likely to be the utility-scale segment due to the focus on grid management and stability, as led by the transmission system operator (TSO). The latter's auction-based capacity allocation steps could change the French storage market dynamics rapidly.

Trend in Aggregate Stationary Storage Capacity



Source: BNEF

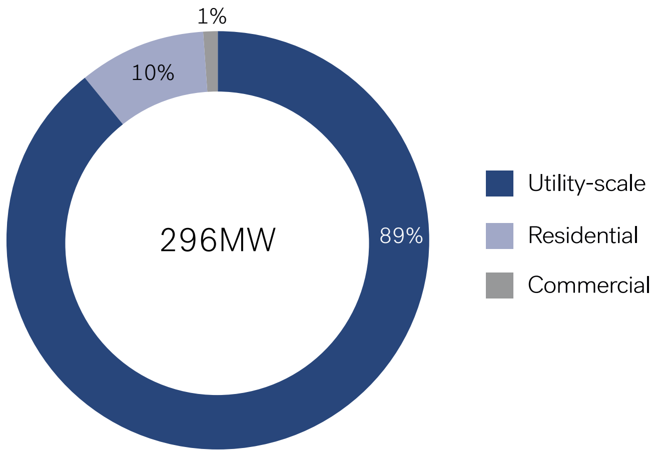
Trend in Pumped Hydro Storage Capacity



Source: IRENA

France

Existing Energy Storage Capacity by Broad Segments



Source: BNEF

So far, TSO's grid-scale storage capacity requirements have mainly been around the need for network stability. For the most part, the operators provide primary frequency response (stabilization for frequency deviations generally within 10 seconds). The market expansion will, however, be contingent on a broader scope of opportunity, such as ancillary services for grid management. In this regard, the existing capacity base is constrained for options. For instance, one of the major battery-based storage operators, TotalEnergies, with 61MW installed capacity, has services limited to primary frequency response.

While battery-based storage options play their role, pumped hydropower is the other grid-scale storage segment for grid management. As per IRENA's estimates, French pumped hydro generation capacity has been stagnant at around 1.8GW. It could persist at similar levels unless the tariff or other incentive structure changes for such storage technologies. Notably, the French hydropower generation capacity is among the largest among European Union countries.

Policy and Regulation

The basis for energy storage is laid out in the French Energy Transition Law, which mandates the expansion of the share of renewable energy in total power consumption. Specifically, the French Energy Code, which includes regulations related to electricity (its generation and related aspects), also covers energy storage based on batteries or other forms. The storage operators are thus viewed as two-way users of the grid tariffs, both as consumers and generators.

The measures on integrating energy storage are primarily led by the French state-owned grid operator RTE. In undertaking its grid management responsibilities, RTE has recently initiated vital steps to enable storage options, especially those based on batteries. One such notable measure is Project Ringo. This EUR80 million (regulator-funded) project involves testing the feasibility of an automated industrial-scale (or utility-scale) battery network. There are three battery storage sites aggregating 100MW, spread across Fontelle in the east of France, Bellac in the west, and Ventavon in the southeast – and are all closer to installed renewable plants.

Project Ringo's ongoing trial aims to establish the techno-commercial case of a software-controlled battery network system. The objective is to deploy a storage system that could absorb excess renewable energy injected in the grid at a point in time and subsequently deliver such energy at a later time point to meet peak demand. Such a storage system could potentially prevent the need for significant transmission capacity addition if successfully deployed. In terms of technology configuration, this is a pioneering project in automated battery networks.

The TSO's grid balancing activity underscores the role of storage (among other options) in the power network. Progressively, the grid power balancing market (involving multiple parties on either side of injection and drawal) has been opened for energy storage facilities. Since 2014, storage units (other than hydro) have been permitted to participate in frequency ancillary services. For now, such participation is limited to the automatic frequency restoration reserve category. As per the latest system balance report, about 190MW of battery capacity was certified for the overall frequency containment reserve (FCR) in the ancillary service domain. There are expectations of enhanced participation in battery-based storage in the near term.

As part of the steps for attracting competitive storage capacities in the market, RTE also conducted an auction in 2020. Of the total 1,500MW of bids offered for the tender, 377MW of aggregate capacity was allocated across 12 companies. The auction was conducted as part of RTE's capacity mechanism in which it selects operators for allocating grid management capacity in seven-year contracts. Expanding this market could prove to be a lucrative opportunity, especially with the rise in renewable energy penetration.

France

Market Developments and Opportunity

The French energy storage market is gradually getting more amenable to private investments. The RTE's capacity market auction in 2020 was just one segment in which seven-year contracts were awarded. The FCR segment is the other potential revenue stream where battery assets could become instrumental for the typical short-term (response time up ranging from 30 seconds to 15 minutes) grid imbalance requirements. Furthermore, the automated frequency restoration reserve is gradually picking up for battery storage. The European energy crisis postponed the planned auctions in this segment.

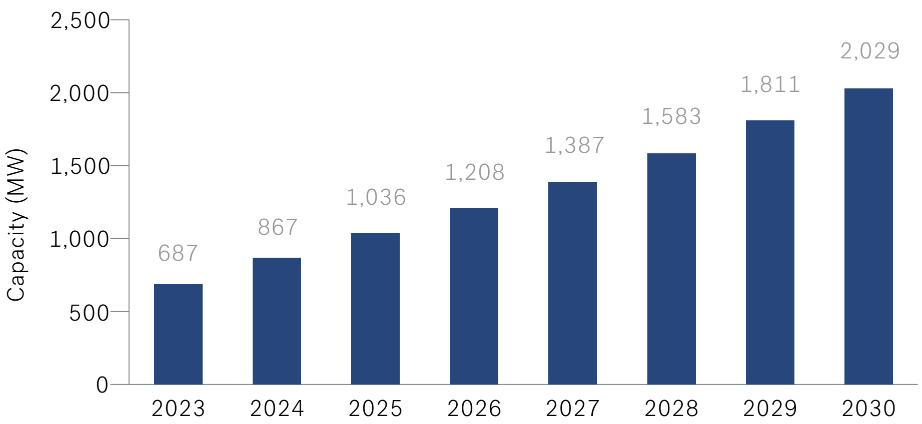
The case for private/independent battery storage providers is also reinforced by regulatory constraints on TSOs. Considering the conflict of interests involved (besides the monopolistic position in the market), the TSOs cannot own battery-storage facilities that participate in power market transactions. It indicates that the TSOs must contract such capacities as may be warranted for the grid management demands.

For now, some of the critical battery storage capacities commissioned are part of the tendering process in the recent past. Some of the significant battery storage systems commissioned in this regard are by TotalEnergies (25MWh capacity as of May 2022 in Carling) and EVLO (9MWh capacity under development in the French Bourgogne-Franche-Comté region). TotalEnergies has the credit for commissioning the largest battery-based storage capacity in France. Among other vital ventures, Project Ringo involves notable players, including Nidec, SAFT, and Schneider Electric, for batteries and overall electronic and software development.

Investments for storage facilities are finding another avenue through hybrid solar power projects. In August 2022, the renewable energy group BayWa r.e. was selected to develop a 40MW solar PV plant with attached battery-based storage (planned at a 2-4 MW two-hour system). Previous renewable energy tenders found similar projects finding capacity allocated due to competitive bids. In January 2021, the auctions done for self-consumption renewable energy projects in French island areas involved allocating 57MW worth of solar-plus-storage projects, with each MW of such projects combined with at least 0.5MW of battery storage (as per bid requirements).

Outlook

Projected Energy Storage Capacity Addition



Source: BNEF

The auction-based route of allocating grid-scale storage capacities presents a tentative visibility of the market opportunity for prospective developers and investors alike. Though the next batch of auctions is yet to be formally announced, the introduction of batteries in RTE's grid balancing mechanism and the market entry of battery suppliers/technology providers provide pointers to the trend ahead. As per the BNEF estimates, a gigawatt-scale of capacity addition is expected over the next couple of years.

With renewable energy integration acting as the only driving factor, the role of storage facilities in the power network is likely to become more critical. One crucial factor in this regard is the transmission infrastructure's requirement for expansion and refurbishment. About EUR20 billion worth of investment is projected in RTE's ten-year development plan (2021-2030). Storage facilities will play an essential part in this equation. The feasibility of Project Ringo (aimed at completion by 2025) could help defer some of the planned investments.

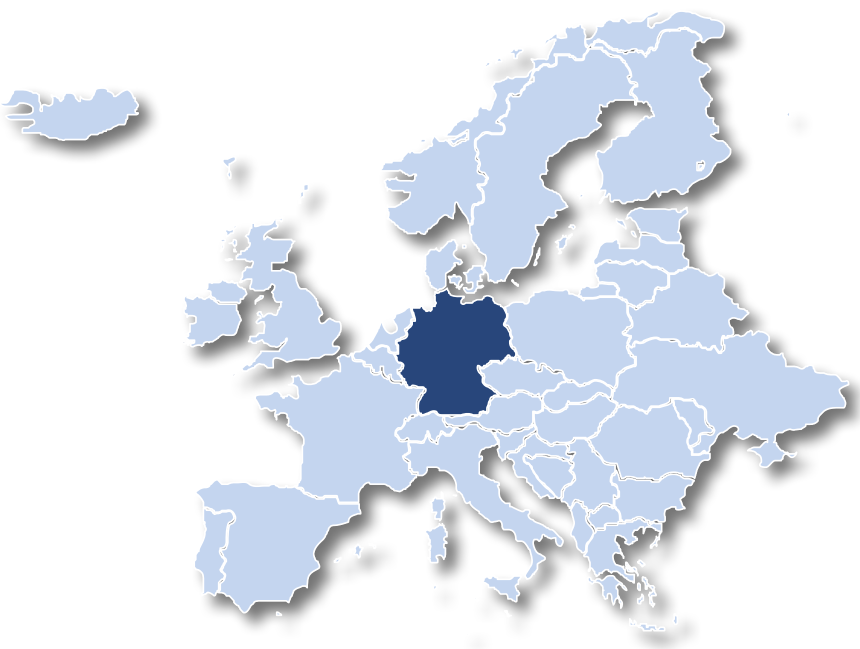
There are also possibilities that storage capacities may not be enough to manage the scale of transition underway. The planned phaseout of nuclear and thermal power capacities is a crucial reason for such concern. RTE's transmission planning projections (as of October 2021) show that by 2050, the inevitable rise in renewable energy must be supported by thermal power generation for dispatch support, assuming no revival of the nuclear-based capacities. Such a projection implies that upcoming grid-scale energy storage capacity may still fall short of the requirement.

Germany

Germany's decarbonization and climate change goals hinge on getting an energy transition done as seamlessly as possible. The path to achieving it is not simple or predictable, as evident in the aftermath of the Russia-Ukraine armed conflict. With an accelerated pace of renewable energy capacity addition, the energy storage option is complementary for grid stability and reliability. In the German context, residential battery storage is the other primary growth driver, emerging as an offshoot of home-based solar PV systems. Even as short-term challenges persist, the position of energy storage is strengthened with the rise in the share of intermittent energy.

GDP (Current Prices) USD (2021)	4,262.77bn
GDP Growth Forecast (constant prices) (2022-2026)	1.35%
Currency	Euro
Country Credit Rating (S&P)	AAA
Energy Storage Capacity* 2021	2,973MW
Renewable Energy Share 2021	37%
Energy Storage Outlook 2030	18GW

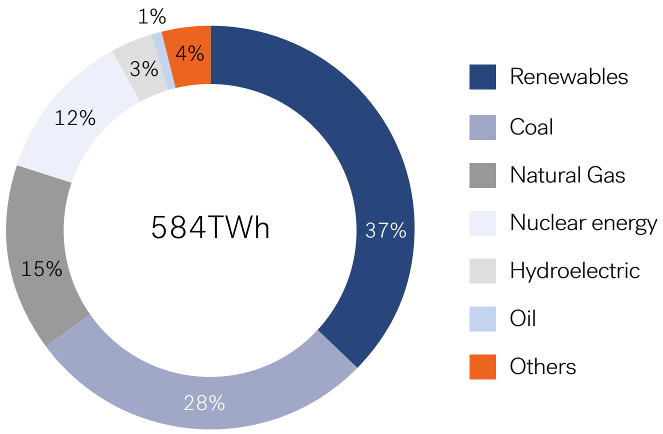
GDP Source: IMF WEO, S&P and IRENA
*Excluding Pumped Hydro



Germany

Energy Mix and Case for Storage

Electricity Generation by Fuel Type (2021)



Source: BP Energy Statistics

Close to 60% of Germany's power generation capacity is based on conventional energy sources (including hydropower). The energy transition is among the top policy priorities in the country. The German public policy statement of Energiewiende sets the agenda for decarbonization and phased closure of coal and nuclear power plants while rapidly enhancing the share of renewable energy. Lately, there has been a push to accelerate the transition towards renewable energy – the government is considering a 100% share by 2035, advancing it from the 2040 planned earlier.

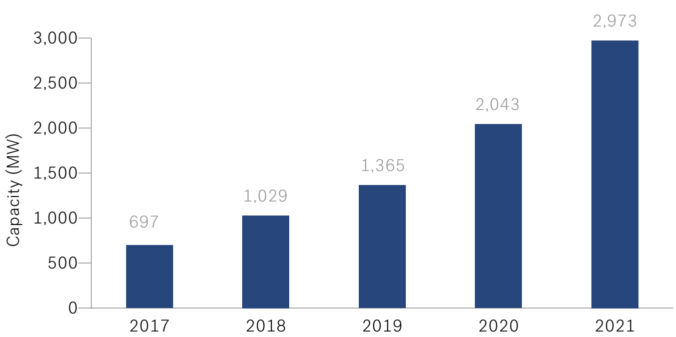
The advancement of renewable energy targets (prompted mainly by the gas crunch) imposes a significant load on the power network. The transmission system operators (TSO) are already managing high volatility in the network, but this will be progressively under strain. Even with capacity augmentation underway, the thrust is on having the flexibility to handle the influx of intermittent energy supply and diverse demand segments. One primary avenue of flexible capacity is energy storage, especially at the grid scale for the transmission network. In Germany, energy storage can effectively help counterbalance the gap in transmission assets required to manage the upcoming demand at short notice.

The country's nascent grid-scale energy storage will play a vital role in facilitating the shift in the energy mix. While most of it continues to be led by hydropower (both pumped storage and conventional), there is a gradual rise in utility-level storage to meet the demand for grid support and stabilization. With the grid's asset augmentation lagging, a rapid scale-up in storage assets could become a bridging resource.

Capacity: Status and Trend

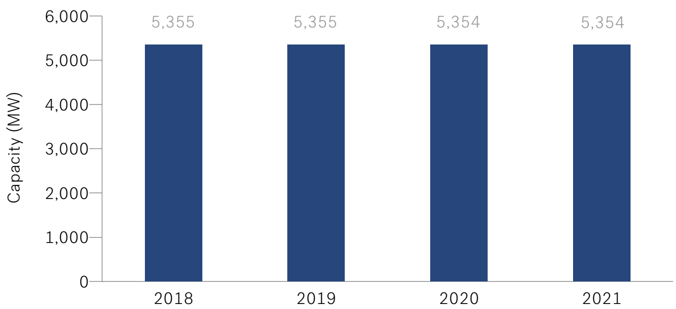
The German energy storage market is yet to gain utility-scale capacities commensurate with its rising renewable energy penetration. Part of the reason could be the role of hydropower generation in managing peaking requirements. Yet, the growth has been impressive, with a CAGR of 43% registered during 2017-2021.

Trend in Aggregate Stationary Storage Capacity



Source: BNEF

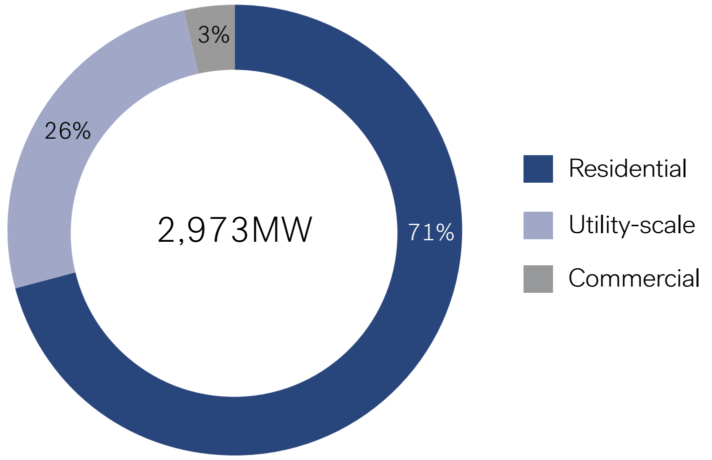
Trend in Pumped Hydro Storage Capacity



Source: IRENA

Germany

Existing Energy Storage Capacity by Broad Segments



Source: BNEF

So far, growth has been through the volumes in the residential storage market segment. The volumes are much more prominent in the residential market than others due to the broad reach of solar-powered residential systems in both grid-connected and off-grid mediums. Capacities are also finding traction through the advent of hybrid storage projects (storage paired with generation projects). This includes not only wind-storage or solar-storage combinations but also hydro-storage ones. However, there is a much more significant and untapped role for utility-scale storage systems in the grid ancillary services comprising secondary reserve requirements.

Policy and Regulation

Germany's focus on energy transition and the support extended constitute an essential part of the framework towards the country's energy storage business. In March 2022, the government announced budgeting of EUR200 billion for industrial transformation projects that include a gamut of technologies supporting the energy transition. Renewable energy projects are an integral part of the scheme; thus, energy storage-based projects are expected to be beneficiaries.

In June 2022, the German Parliament ratified the amendment to existing legislation to define energy storage as an asset in the overall electricity business. This is an essential regulatory measure, as energy storage systems were so far identified either as generation or consumption-based assets depending on the charging or discharging involved. There are expectations that instances of mistargeting or unnecessary complexity can be avoided with a clear definition. Notably, the amendments also helped widen the ambit, as they included energy storage assets (instead of just solar PV earlier) for the norms related to eligibility for a streamlined digital grid connection process.

While the loophole in defining energy storage was addressed, the country's regulatory framework has been cognizant of the storage business and its role in the power network. The regulations on energy and electricity specifically have provisions to avoid double-charging on energy storage. In addition, the state-owned investment and development bank kfW introduced a revamped funding scheme that actively helps the case of residential storage, such as in terms of the required share of energy to be injected in the network, fair value replacement guarantee for the promoted batteries, etc. Germany is among the few in the European Union to have tariffs specifically for energy storage systems.

The country's biannual innovation auctions are an essential driver for the utility-scale energy storage capacity market. The latest one in August 2021 awarded 42MW/84MWh of storage, due for commissioning by 2023. The government has lately indicated its plans to expand the size of the auction-based capacity allocation to build up the project pipeline. One can thus expect better visibility of investments in this regard.

Recently, the first steps were taken towards setting up a pan-European platform to provide secondary reserve critical in maintaining the grid's operating frequency. This European automatic frequency restoration mutualization project (aFRR), also called the PICASSO project, will help countries to share their balanced energy. Germany and Austria were the first two European countries to have accessed this platform on June 22, 2022.

Germany

Market Developments and Opportunity

The residential segment plays an essential part in the German energy storage market. The prime reason is residential solar photovoltaic systems' rapid growth and penetration. About 64% of the German solar PV systems under 10kW capacity had energy storage capability attached (BSW Solar Survey, 2022). As per the Energy Storage System Association (BVES), the residential segment held about half of the sector's total revenue of EUR8.9 billion as of the end of 2021. With a rapid rise in unit sales, home-based battery storage capacity is about 2.5GW (end-April 2022).

On the other side, the utility segment registered a 25% revenue growth in the same year, to reach EUR2.3 billion, led primarily by pumped hydropower storage. However, utility-scale battery systems had a spike in growth during 2021, with revenue rising over six times than the previous year's. The energy shortages due to the Russia-Ukraine armed conflict reinforced the position of battery-based residential solar PV systems and storage-based renewable energy projects. The momentum extended to commercial and industrial (C&I) user segments. Tesvolt, one of the battery-based storage providers for C&I users, registered a 200% rise in orders by March 2022.

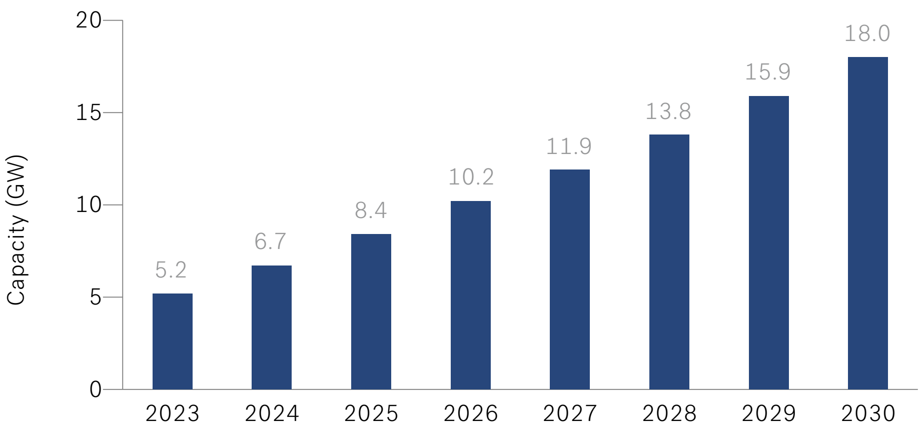
The opportunities in utility-scale energy storage projects are also expanding from the emergence of merchant markets. RWE, for instance, has been developing partial merchant projects – most of them benefit from existing grid connections at locations for other generation assets in the previous year. One of the partially merchant projects is the battery-plus-hydro power project. The project targets the grid ancillary service segment (short-run stabilization), while the hydropower segment is for the longer-duration energy response.

In March 2022, the UK-based investment fund Gore Street acquired the 22MW Cremzow project from Enel. For this investor, it was the first such investment outside UK and Ireland. Similarly, in July 2022, the investment funds of Swiss Life Asset Managers acquired a 50% stake in Germany's battery storage platform BCP Battery.

Lately, developers have been utilizing the decommissioned conventional energy assets and their related infrastructure (such as transmission lines) to set up new energy storage facilities. The Munich-based developer The Mobility House (THM) partnered with Daimler to set up a 10MWh storage facility at an abandoned coal-based power plant in Germany's Werdohl-Elvering. Old or abandoned coal-based power plants are also candidates for retrofitting into large thermal storage-based storage. In Essen, for instance, studies have been underway to test the feasibility of exploiting salt caverns for energy storage. In another venture, CMBlu has been working with RWE Gas Storage West GmbH to convert the latter's gas storage caves into batteries.

Outlook

Projected Energy Storage Capacity Addition



Source: BNEF

The residential solar power capacity growth is likely to continue driving home-based battery storage. BVES projections point to a 67% rise in unit sales by end-2022 as batteries become an integral part of residential energy consumption. The utility-scale storage will, however, be an essential part of the equation for its role in grid management and bringing onstream the flex generation capacity critical in the energy transition.

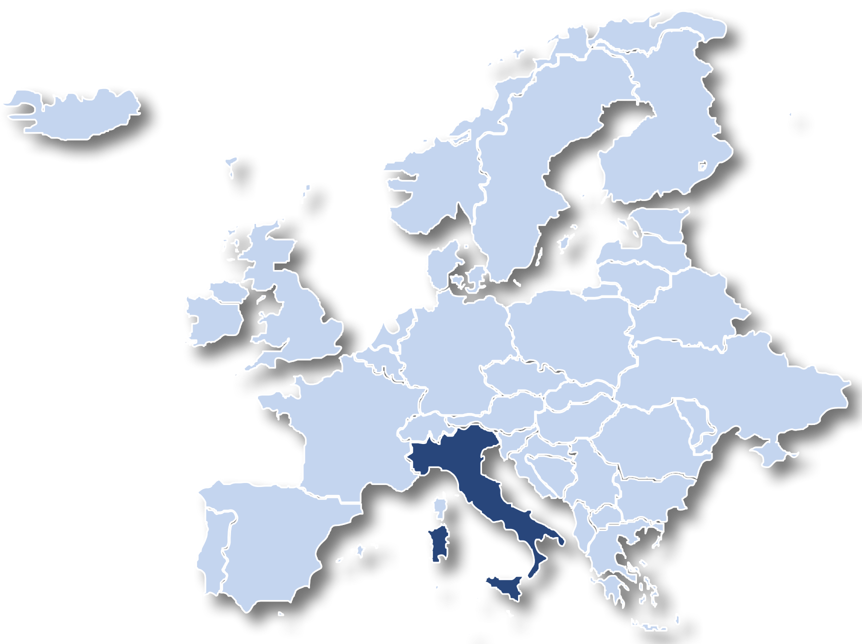
Despite a strong demand outlook, the short-term energy crisis will likely delay some of the investments toward energy storage. The pressure is on securing existing baseload power supplies that face an acute shortage due to the disruption in natural gas. There is a rethink in the planned phaseout of coal-fired power generation. In July 2022, the Parliament approved the re-activation of mothballed coal-based power generation to address power demand and manage scarce natural gas supply. From the energy mix option perspective, such measures could, in effect, push back some of the flexible energy resources, such as those of grid-scale energy storage and others. Grid operators are also likely to hold back on energy storage systems in the short term as such baseload power sources are brought online.

Italy

Italy has set modest targets for decarbonisation as per its National Energy and Climate Plan ("PNIEC") compared to its European peers. The PNIEC targets only a 55% share of renewables in electricity consumption by 2030, vis-à-vis 75%+ share targets set out by Austria, Denmark, Germany, Portugal, Spain, Sweden and the Netherlands. Italy has been conspicuous as the only country among G7 nations not to commit to overwhelmingly decarbonising electricity generation by the 2030s. As the energy transition picks momentum, Italy's energy storage market, predominantly skewed towards residential rooftop solar-linked battery energy storage systems ("BESS"), is likely to see a more significant share of utility-scale storage. The current surge in gas prices in Italy could have a domino effect on decarbonisation initiatives, leading to an accelerated energy storage market development.

GDP (Current Prices) USD (2021)	2,101.28bn
GDP Growth Forecast (constant prices) (2022-2026)	1.29%
Currency	Euro
Country Credit Rating (S&P)	BBB
Energy Storage Capacity* 2021	379MW
Renewable Energy Share 2021	25%
Energy Storage Outlook 2030	7,418MW

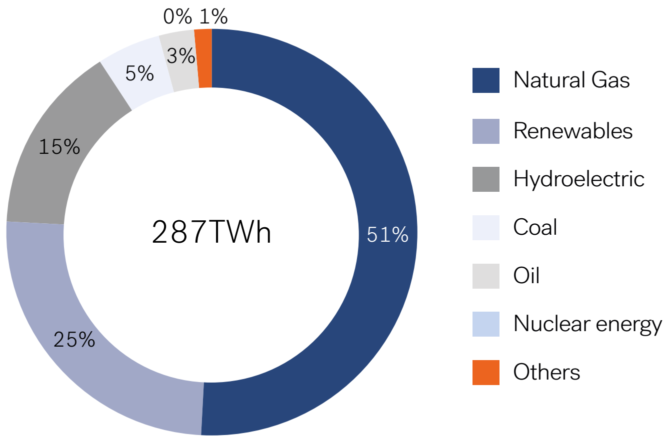
GDP Source: IMF WEO, S&P and IRENA
*Excluding Pumped Hydro



Italy

Energy Mix and Case for Storage

Electricity Generation by Fuel Type (2021)



Source: BP Energy Statistics

More than half of electricity generation in Italy is sourced from fossil gas, with renewables and hydroelectric power constituting 40% share cumulatively. Energy security has been under scrutiny as runaway gas prices have contributed to the tripling of wholesale electricity prices in 2021. The Russia-Ukraine conflict has exacerbated the energy situation in Italy, with the energy import bill projected to balloon to €100 billion in 2022, more than double the €43 billion in 2021. This has prompted a concerted push towards a faster energy transition, with solar and wind power prices being more than 3x cheaper than natural gas. Regulatory bottlenecks for wind and solar projects are being streamlined through legislative intervention while there is now an emphasis on utility-scale capacity installation. Italy is looking to add 8GW in renewable capacity annually to meet its 2030 targets.

Italy imports three-quarters of its energy requirements and is susceptible to price shocks. It is estimated that the inflation in energy prices will erode three percentage points off its GDP in 2022. As policymakers increasingly turn to renewables-based generation to manage the prevailing energy crisis, the electricity grid's stability will come under pressure to manage intermittent, non-synchronous renewable-based power generation. Grid-scale energy storage is a viable option to inject capacity and flexibility into the grid in the shortest time. This is evident from the 1.1GW capacity allocated to battery-based energy storage in the latest capacity auctions held in February 2022.

Transmission system operator (TSO) Terna has launched a 2021-25 Development Plan for the national electricity transmission grid and subsequently increased the Capex allocation to a massive €10 billion in investment to accelerate the energy transition underway. Besides upgrading the transmission network, significant changes are underway to accommodate an additional 40GW in renewables capacity by 2030. Notable among these are grid-connected storage systems to provide fast reserve services to the grid. Contracts have been awarded to Enel and Greece-based Mytilineos S.A in this regard.

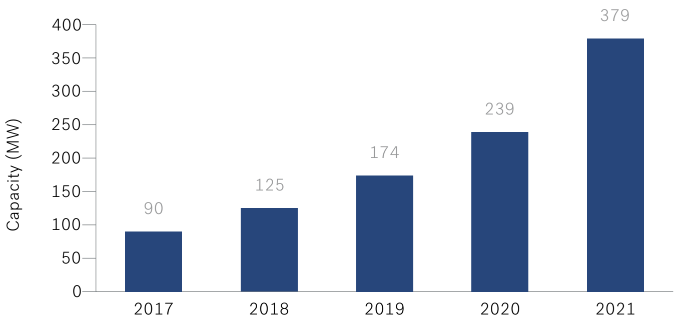
Italy's energy storage market is likely to transform from a predominantly residential one to a structure where utility-scale accounts for more than 60% of the cumulative storage capacity of 7.4GW by 2030. There are also plans to expand pumped hydro storage capacity, but the planned capacity addition of 3GW is unlikely to be ready by 2030. Hence, battery energy storage is expected to be the preferred energy storage technology to support Italy's decarbonisation initiatives through this decade.

Italy

Capacity: Status and Trend

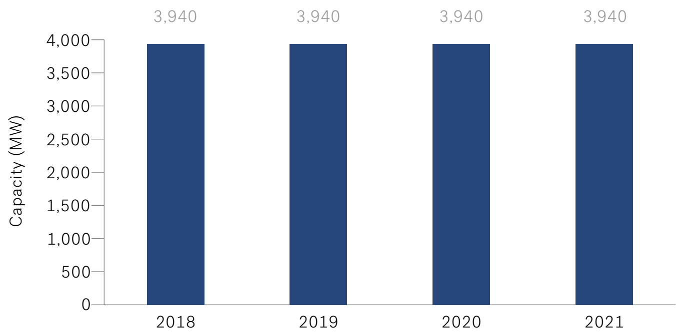
The cumulative energy storage capacity, excluding pumped hydro storage, stood at about 379MW in 2021. Italy also has a pumped hydro storage capacity of 3.94GW, the seventh largest globally. However, pumped storage is entirely legacy capacity, having been static over the last two decades. The residential consumer segment has primarily driven growth in energy storage capacity, with installed capacity expanding by more than six-fold from 31MW in 2017 to 268MW in 2021, accounting for more than 70% of cumulative installed capacity in the country.

Trend in Aggregate Stationary Storage Capacity



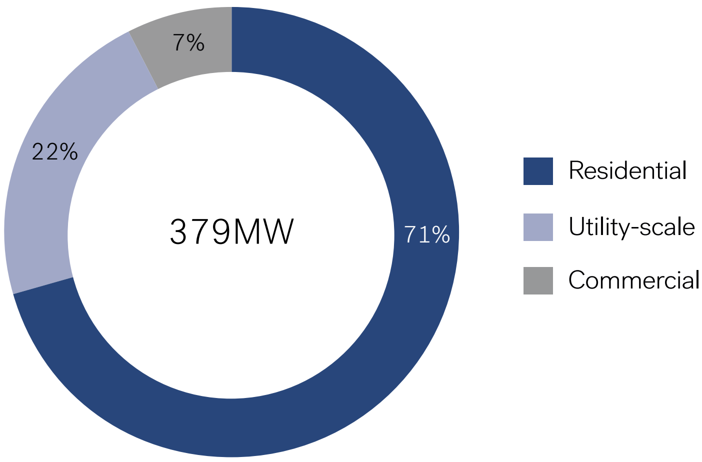
Source: BNEF

Trend in Pumped Hydro Storage Capacity



Source: IRENA

Existing Energy Storage Capacity by Broad Segments



Source: BNEF

The residential rooftop segment has been a key driver for the solar PV market in Italy in recent years. Incentives such as a 50% tax credit and a 110% Superbonus incentive scheme for purchasing BESS have been a vital catalyst that contributed to 460MW of storage capacity being added in 2021, almost 80% of the total storage capacity added in the country during the year. Italy ranks second to Germany in the overall European residential battery storage sales market. This is led primarily through the sale of solar PV systems and the batteries installed are a mix of grid-connected and behind-the-meter (or off-grid). Notably, there are expectations of a phaseout in net-metering by 2025, after which the behind-the-meter home batteries (or distributed energy storage) could play a more significant role than done so far.

Italy

Policy and Regulation

Italy's post-COVID recovery and resilience plan, approved by the European Commission, earmarks €191.5 billion, with a 37.5% share allocated to green transition. Significant allocations have been made for energy efficiency in residential and public buildings, sustainable mobility, and waste and water management. Given the focus on energy efficiency, energy storage projects will likely be beneficiaries of the enhanced budgetary allocations. As per the Italian press agency Ansa, the country expects 5.1GW of renewables capacity to be added in 2022.

With 40GW of renewable generation capacity set to be added to the Italian electricity grid by 2030, policymakers are revamping the policy framework to attract more investment into the energy storage segment. Italy introduced a simplified permitting process for small energy storage systems in 2021 and is looking to finetune the mechanism for utility-scale storage to catalyze investments. To this effect, energy storage was included in the capacity auctions held in February 2022, with Enel being awarded a contract for 1GW BESS capacity to be operational from 2024. In 2020, TSO Terna awarded 250MW of five-year contracts to operators for BESS to provide fast reserve frequency response services in a pilot auction that was oversubscribed.

Since 2019, the transmission system operator Terna has been selling capacity under UVAM demand response contracts as a hybrid product offering for its ancillary services market (also referred to as MSD). The introduction in 2019 was meant to introduce battery units among other market participants (including conventional generation, renewables, and electric vehicles, among others) in such contracts.

The prevailing energy crisis in Italy has precipitated a rollout of urgent measures to contain electricity costs by developing renewables through Law Decree 17, published in March 2022. Among other provisions, the implementation of storage systems with a maximum capacity of 3MWh for every MW of solar PV capacity has been deemed eligible for fast-track approval. Storage systems with less than 10MW capacity have been exempted from building permits, although streamlined environmental, landscape and connection permissions are still required. A combination of regulatory changes and attractive rebates like the 110% Superbonus scheme has led to the accelerated mobilization of storage capacity, which touched 60% of 2021's full-year figure by the end of Q1 2022.

Market Developments and Opportunity

Distributed solar has been vital in adding energy storage capacity in Italy. As per the Italian Renewable Energy Association ANIE Rinnovabili, 122,279 storage systems representing a total capacity of 720MW were installed by 30 June 2022, close to doubling the cumulative installed capacity by the end of 2021. 99.9% of the installed storage systems were paired with solar PV systems, of which 97% were residential. Besides attractive fiscal incentives, escalating power prices have contributed to a sharp pickup in residential solar and storage installations, with 90% of PV installers offering storage solutions.

The utility-scale segment, which has had a marginal presence with 83MW storage capacity till the end of 2021, is expected to pick up momentum. A cumulative storage capacity of 346MW, comprising 250MW from Terna's Fast Reserve pilot project and 96MW awarded at the capacity market auction held in 2019, is expected to come online in 2022. BNEF anticipates the utility-scale storage segment to overtake the residential segment by 2024 and continue growing to 4.6GW cumulative installed capacity by 2030, accounting for more than 60% of the 7.4GW storage capacity projected to be installed in Italy by then.

Legislative Decree no. 199/2021, announced in December 2021, increased the threshold of access to incentives to projects having a capacity of up to 1MW and streamlined the process for prosumers. This is likely to compress the break-even period of self-consumption projects, particularly within the commercial and industrial (C&I) segment, from 5-6 years under the net metering regime currently. Consequently, the adoption of energy storage systems within the C&I segment is expected to increase.

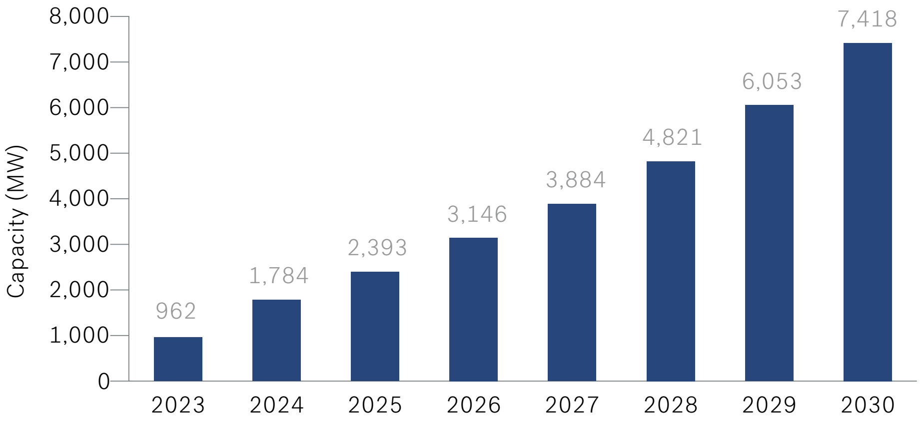
Expansion in the market potential for the Italian battery energy storage market has spurred private sector investments in recent times. Spain-based Powertis has teamed up with German investment firm Aquila Capital to co-develop 421MW of solar PV and 90MW of energy storage projects in Italy in January 2022. Barclays-backed Energy Dome announced the launch of the company's first CO2 battery in Sardinia in June 2022. Ireland-based developer Aer Soléir announced that it had signed an investment and co-development deal for 510MW battery storage projects in Italy with Turin-based Altea Green Power in July 2022. Macquarie's Green Investment Group, through its subsidiary company, Cero Generation, and asset manager NextEnergy Group are deploying capital in large agrivoltaics projects in Italy with significant energy storage components.

Industry players within Italy's renewable energy industry concur that further liberalization of rules around energy storage is needed to accelerate market development. There is a strong likelihood of allowing battery storage assets, slated for delivery in 2024, to participate in the Ancillary Services Market (MSD) from their first year of commissioning. The additional revenue stream will enhance the financial viability of storage projects, attracting further investments in the segment. Retirement of coal-based baseload capacities will also likely trigger a renewed call for additional storage capacity to help bridge the ensuing capacity gap.

Italy

Outlook

Projected Energy Storage Capacity Addition



Source: BNEF

High power prices are likely to ensure that residential solar continues to expand at elevated levels, driving Italy's home-based battery energy storage market. Surveys from EUPD Research indicated that ~90% of solar installers in Italy offered storage options, with the remaining 10% pointing to do so by the end of 2022. The demand for storage is apparent from cumulative installation statistics – 112MWh (2020) increasing to 431 MWh (2021) and 632 MWh by the first half of 2022, which shows an apparent acceleration in deployment, owing to high energy prices as well as attractive incentives on offer. As the experience of other countries (European and Australia, in particular in APAC) shows, the behind-the-meter energy storage segment could assume a more significant role in the scheme of grid management.

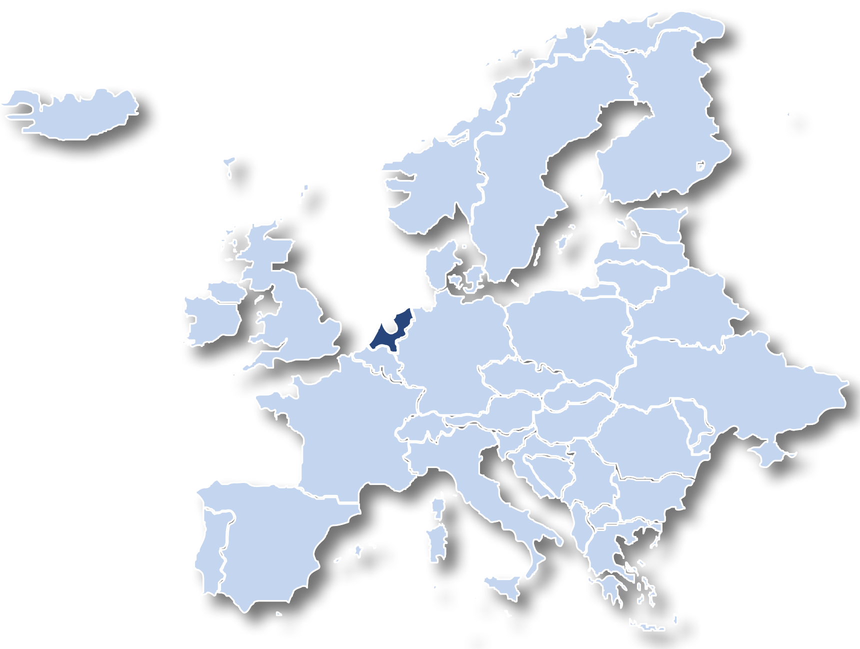
Despite solid growth prospects, the prevailing regulatory structure has worked to hinder the accelerated expansion of the energy storage market. Permitting processes for large storage projects remain complex despite efforts to streamline and simplify. The abbreviated interval between auction and project delivery can be a deterrent, especially for new entrants. Despite increased access to grid services, storage asset operators still have no clarity on reimbursing almost 35-40% of their Capex. The ancillary market appears to be the only visible revenue stream enabled by the regulator or TSO. Typical storage developers/operators would require multiple revenue streams/stacks to monetise the assets and ensure financial viability. Lastly, as coal-based capacity is retired, there is still a solid case for considering fossil gas-based power generation as an interim measure till the transition to renewables is stabilized. While the competition between gas and renewables will remain, given the overwhelming share of the former in the energy mix, the retirement of fossil-fuel-based capacity will likely create investment opportunities for both.

The Netherlands

With the rapid growth in renewable energy capacities, The Netherlands aims to make the best efforts at achieving its climate and decarbonisation objectives. The capacity pipeline could expand further with a rise in budgetary resources to subsidize the projects. In doing so, the power network reliability could become a challenge in the absence of requisite energy storage – which is critical for grid management and deferment of costly grid expansion. The recent storage capacities commissioned in the network reflect gradual progress. Much more is, however due on the part of regulatory authorities to ensure the right market design.

GDP (Current Prices) USD (2021)	1,013.52bn
GDP Growth Forecast (constant prices) (2022-2026)	2.04%
Currency	Euro
Country Credit Rating (S&P)	AAA
Energy Storage Capacity* 2021	52.5MW
Renewable Energy Share 2021	33%
Energy Storage Outlook 2030	750MW

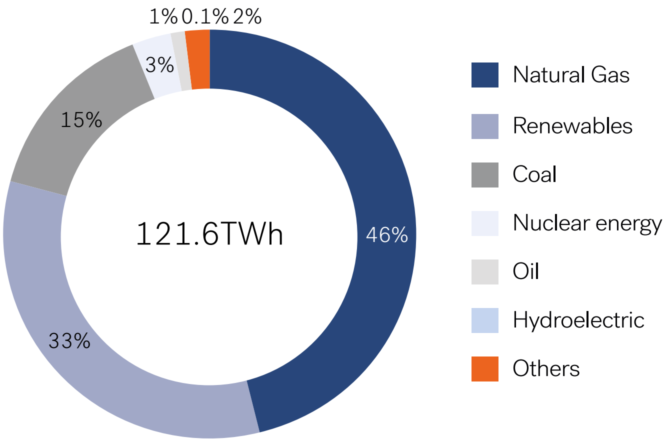
GDP Source: IMF WEO, S&P and IRENA
*Excluding Pumped Hydro



The Netherlands

Energy Mix and Case for Storage

Electricity Generation by Fuel Type (2021)



Source: BP Energy Statistics

As a policy goal, The Netherlands has a target of sourcing 100% of its electricity from renewables by 2050. The targeted Greenhouse gas emission reduction is 49% by 2030 and 95% by 2050 (compared to the 1990 levels of emissions). While the authorities have been allocating budgetary resources to incentivize renewable energy sources, the dependence on hydrocarbon energy resources remains high. Without additional measures, the country could miss its climate mitigation targets for 2030. One can thus expect more significant investment and policy attention towards renewable energy, among other measures for the emission control targets.

As one of the examples of steps toward energy transition, the government passed a law in 2019 to phase out the coal-based power generation capacity by 2030. The lower-efficiency and ageing assets are first in line for shutdown (planned by 2025). Meanwhile, the renewable energy capacity pipeline has expanded rapidly and is progressively accounting for a sizeable share of the grid supply. Against this backdrop, the pressure on network management is rising to balance the diverse and intermittent supply and ensure grid availability (in the face of a frequent surge in supply against limited network absorption capacity). The battery storage capabilities are thus assuming a critical position as network operators seek grid reliability in the most cost-effective route feasible.

Capacity: Status and Trend

The Netherlands' energy storage market is yet to take off like other key markets, such as the UK or Germany. Most of the capacities commissioned earlier were standalone for either testing the technology or meeting select objectives (short-duration balance and renewable energy integration). In many cases, the installations were also utilised as charging infrastructure for battery-based automobiles.

A lack of appropriate incentives has deterred utility-scale battery storage capacities so far. Yet, the situation may gradually change with the measures the regulator initiated and the pilot projects underway to establish feasibility. Commissioning of some significant capacities is also expected to add market momentum. In October 2022, the country's largest energy storage project, the 24MW GIGA Buffalo project, was commissioned. The project involves a co-location with wind and solar power generation units.

Co-location of storage with renewable energy generation could gain traction in the future. In March 2022, for instance, the Swedish power multinational Vattenfall commissioned the Energypark Harinvliet project, which involves a combination of wind (22MW), solar (38MW), and battery storage (12MWh). Besides managing the generation intermittency, the batteries will also contribute to grid balancing roles.

The Netherlands

Installed Battery Storage Capacity in The Netherlands (2021)

Project name	Application	Year of Commissioning date	Capacity (MW)
Giga Rhino Netherlands	Short duration balancing	2020	12.0
Leclanche and S4 Energy Almelo	Short duration balancing	2020	8.8
Alfen Hartel Rotterdam	Renewables integration	2019	10.0
Amsterdam Arena Second Life Battery	End-user services - Other	2018	3.0
Vattenfall Prinses Alexia	Short duration balancing	2017	3.2
Alfen Lelystad Pilot Project	Technology testing	2017	0.5
VDL Eindhoven	Short duration balancing	2016	1.6
AES Zeeland	Short duration balancing	2015	10.0
Enexis and Alliander Etten-Leur	End-user services - Other	2012	0.4
EcoPower Bonaire Island BV Microgrid	Renewables integration	2010	3.0

Source: BNEF

Policy and Regulation

The country's policy and regulatory framework, while recognising the energy storage assets in the system, is yet to be aligned with the industry's needs. Fundamental regulation changes are due to critical factors such as the charges storage units must pay or the tax incidence. Recent steps taken indicate progress. For instance, since January 2022, the regulatory authorities have exempted storage assets from double taxation on the import and export of power. With the amended regulations in place, storage units could avoid double taxation if the storage operator had a large-scale consumption connection and declared its exemption from the levy to the supplier.

Yet, there are other norms overdue for revision. The energy storage assets are liable to pay grid fees (as a consumer of grid power). Such an arrangement is misplaced as the same storage assets are also expected to inject the power back into the grid at a designated time slot and capacity. With a typical standalone battery storage asset charging entirely from the grid, the charges levied could be a sizeable part of operational expenditure. The regulatory gap in this context must be closed as soon as possible to enable new capacities. Notably, the European Union guidelines suggest scrapping the grid transportation cost for energy storage. It is thus also incumbent on the country to revise its regulations in this regard.

In other instances, the regulations regard storage assets as power generation sources. Grid access is one such instance. Battery storage operators, under existing regulations, must contract network capacity for both charging and discharging. Such a process shuts out the batteries during times of network congestion. With the rising share of renewable energy supply (intermittent), grid congestion frequently impacts storage assets. Pilot storage projects, led by network operators, will be exploring the possibility of deploying large-scale batteries to circumvent the issue of renewable energy clogging the network.

Among other policy priorities, the Dutch government plans to gradually phase out the net metering facility for households starting in 2025. Without incentives to inject power into the grid, battery storage will be an attractive option for residential solar PV systems. It will be a staggered process, though.

The Netherlands

Market Developments and Opportunity

Alternative technologies are under active consideration for grid-scale deployment. S4 Energy, a Dutch company, specialising in flywheel technology, partnered with ABB for a storage project combining battery storage and flywheels to ensure a stable grid frequency level. The system involves a 10MW battery and a 3MW flywheel connected to a wind farm. The project could help establish key parameters of costs and technical performance for replication ahead.

The co-location of battery storage with generation capacities is another untapped area in the industry. It could act as a catalyst for renewable energy projects (as storage improves dispatchability) and help the case for market participation of grid-scale storage capacities. As per grid operator TenneT, the co-location of solar and grid capacities could add 7.5GW of solar capacity to the Dutch power system.

Network operator Liander and GIGA Storage have launched pilot projects for large-scale battery storage systems to check for ways to utilise grid capacity efficiently. The projects will come up in the Dutch cities of Amsterdam, Alkmaar, and Leylstad. The aim is to test how batteries can operate in specific time-bound contracts for the available grid capacity and whether there is a business case for storage assets to offer congestion services in the Netherlands' power system. The expected results in 2023 could help open a revenue stream for the storage operators/developers.

There are proposals to seek the government's budgetary support for batteries linked to residential solar PV. While the net metering system is set to be phased out, the government is also debating over the case for subsidising the storage-based PV systems. The ruling government's coalition parties sought 30% subsidy support for solar systems in this regard. With net metering phased out, storage-linked solar systems could be an essential demand driver.

Outlook

In its ten-year plan document for 2020, the European Network of Transmission System Operators (ENTSO-E) projected 750MW battery storage capacity in the Netherlands by 2030. The requirement is based on the rising demand for grid balancing and related ancillary services in the Dutch power system. The increasing instances of network congestion in the power system are one indication of the requirement ahead.

The Netherlands' grid congestion challenges are partly a manifestation of a lagged regulatory response to grid management and balancing services from private operators (through battery storage or others). Transmission capacity addition lags behind the rapid expansion of solar power capacities. Furthermore, there is the issue of the cost of such infrastructure, which must be passed on to consumers. Battery storage is increasingly proving an effective tool to defer the transmission system's capital expenditure.

The bankability of the projected energy storage projects will squarely lie with the enabling regulations. The existing regulatory norms have gaps that prevent revenue stacking for a typical standalone battery storage unit. The practices followed by other European Union countries are notable examples to emulate. The most important is to define the energy storage role as a distinct asset in the power market.

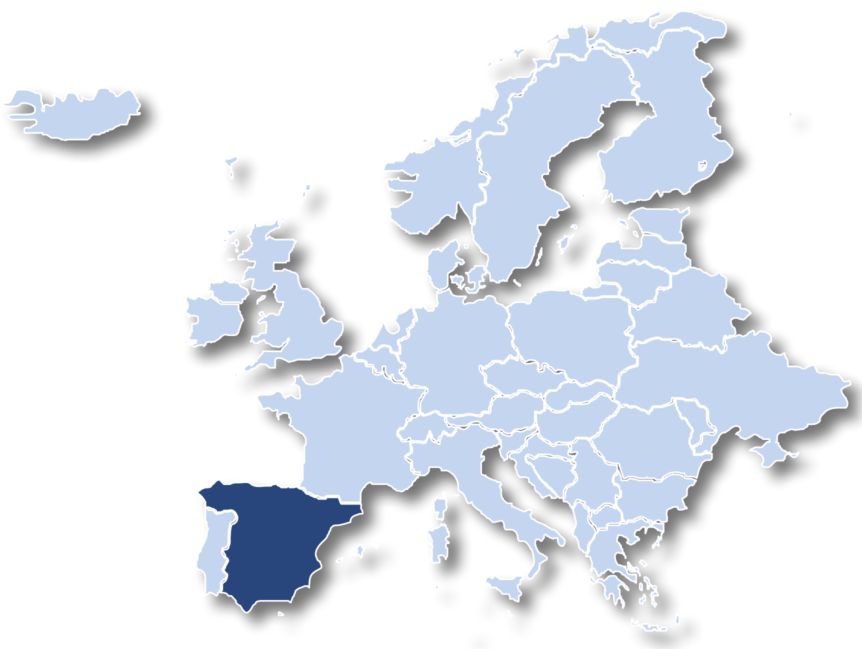
Spain

Spain has registered impressive growth in renewable energy capacities to rank among the leading European markets. Such an increase in renewable energy penetration should ideally reflect the rise of the energy storage market. However, the country's utility-scale energy storage is nascent despite the massive opportunities. Regulations have lagged behind the industry's underlying developments. Investors and developers are thus wary of any investment commitments. Recent policy announcements, such as those of long-term energy roadmap, help set the narrative. The rapid growth in renewable capacities could make grid-scale storage inevitable.

GDP (Current Prices) USD (2021)	1,426.22bn
GDP Growth Forecast (constant prices) (2022-2026)	2.59%
Currency	Euro
Country Credit Rating (S&P)	A
Energy Storage Capacity* 2021	14.8MW
Renewable Energy Share 2021	35%
Energy Storage Outlook 2030	20GW

GDP Source: IMF WEO, S&P and IRENA

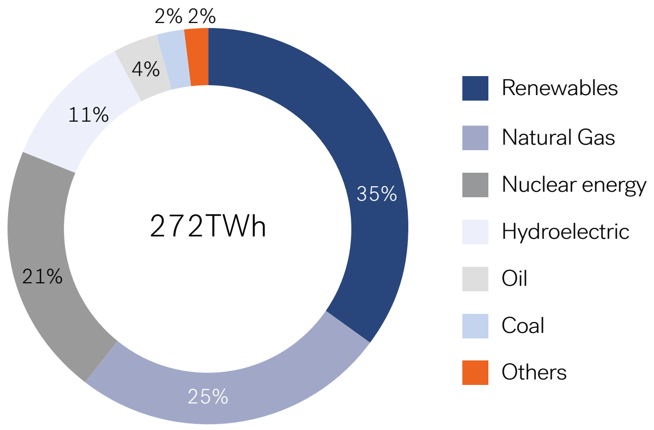
*Excluding Pumped Hydro



Spain

Energy Mix and Case for Storage

Electricity Generation by Fuel Type (2021)



Source: BP Energy Statistics 2022

Spain's energy mix is in the process of a substantive transition. The national target is to achieve a 74% share of renewable energy in 2030 and reach net zero by 2050. Renewable energy generation is already assuming a leadership position – in 2021, it contributed the maximum (96TWh) in absolute terms than any other resource in the energy mix. Wind power is the primary growth driver. It also helps that the country's renewable energy projects are competitive with leading European countries like Germany.

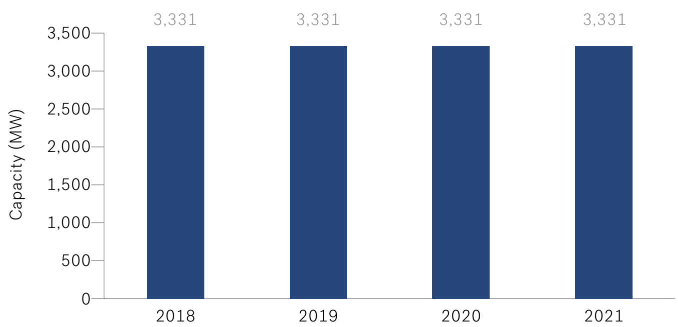
The planned energy transition is also notable for the coal and nuclear-based generation fleet phaseout. In September 2022, for instance, authorities approved the closure of a 1.4GW coal-based plant. More such capacities will be retired gradually. The recent developments in energy constraints due to the Russia-Ukraine conflict have impacted the planned phaseout rate. Yet, the direction of change toward the decarbonisation of the power sector is clear.

The network operator thus has an onerous task ahead to ensure the reliability of the supply when the share of intermittent generation rises and that of the conventional baseload power sources scales down. In this context, the Spanish network operator Red Eléctrica de España (REE) 2021-2026 transmission plan provides indications of the preparation underway. Among other elements, the transmission plan involves €2 billion worth of investment for integrating renewables into the grid. The planned measures are in addition to the government's policy strategy on utility-scale energy storage to enable grid management in the emerging energy mix scenario.

Capacity: Status and Trend

BNEF estimates indicate an installed stationary energy storage capacity (excluding pumped hydropower) of 14.8MW as of 2021. Per the tracked estimates, the installed capacity base primarily comprises projects commissioned for technology testing, among other applications. For the most part, renewable energy developers own and develop such capacities. Iberdrola's Aranuelo project involving 3MW storage was a major one, set up as a storage-linked hybrid solar power project. REE has a few energy capacities commissioned for select roles in its grid management functions.

Trend in Pumped Hydro Storage Capacity



Source: BNEF

The absence of standalone battery storage capacities in the Spanish market reflects the gap in its power market framework. In the current backdrop, hybrid renewable energy projects paired with storage units appear most amenable to the Spanish context. Iberdrola's project in 2021 was one notable example. The are other similar projects in the pipeline. The renewable energy auctions in this regard could help provide traction for this segment.

Spain

Installed Utility-Scale Storage Capacities in Spain

Project	Application	Technology	Year of Commissioning	Power (MW)
Iberdrola Aranuelo Solar Energy Storage Project	Renewables integration	Other technologies	2021	3.00
Acciona Energia Barasoain Energy Storage Project	Technology testing	Lithium-ion	2017	1.70
Gamesa La Muela Microgrid Project	Renewables integration	Lithium-ion	2016	0.21
Gamesa La Muela Microgrid Project	Technology testing	Lithium-ion	2016	0.21
Endesa Gran Canaria Energy Storage Project 1	Renewables integration	Lithium-ion	2013	0.33
Endesa Gran Canaria Energy Storage Project 1	System capacity	Lithium-ion	2013	0.33
Endesa Gran Canaria Energy Storage Project 1	Technology testing	Lithium-ion	2013	0.33
Endesa Gran Canaria Energy Storage Project 2	System capacity	Flywheels	2013	0.50
REE Carmona Energy Storage Project	Renewables integration	Lithium-ion	2013	0.33
REE Carmona Energy Storage Project	Short duration balancing	Lithium-ion	2013	0.33
REE Carmona Energy Storage Project	Transmission services	Lithium-ion	2013	0.33
Toshiba & GNF & NEDO Madrid Energy Storage Pilot Project	Renewables integration	Lithium-ion	2013	0.17
Toshiba & GNF & NEDO Madrid Energy Storage Pilot Project	Short duration balancing	Lithium-ion	2013	0.17
Toshiba & GNF & NEDO Madrid Energy Storage Pilot Project	Technology testing	Lithium-ion	2013	0.17
Endesa Gran Canaria Energy Storage Project 3	System capacity	Other technologies	2012	4.00
Acciona Energia SA Tudela Energy Storage Project	Renewables integration	Lithium-ion	2012	1.10
Red Electrica Lanzarote Microgrid Project	End-user services - Other	Flywheels	2012	0.80
Red Electrica Lanzarote Microgrid Project	Short duration balancing	Flywheels	2012	0.80

Source: BNEF

Policy and Regulation

The regulations provide a basic definition of energy storage, its ownership, functions, and participation in providing services in the energy market. Further, the regulatory norms also describe the grid access for such capacities (in line with power generation) and allow for co-location with new or existing generation capacities. Standalone capacities are thus subject to similar requirements of permits and related procedures to seek transmission access toward the injection of power.

While the legal definition sets the baseline, the framework is incomplete in the absence of specific regulations of market participation. There is a clear need, for instance, to define the role of batteries and other energy storage technologies in major grid management segments, such as ancillary services, where the Spanish market remains untapped. Battery storage capacities are unable to take advantage of the price arbitrage between peak and off-peak wholesale power prices that is common in other markets.

As a step forward, In May 2021, the Spanish authorities introduced norms for the capacity market as a mechanism for flexible sourcing capacity in the network. The planned structure for such a mechanism has two types of auctions – the primary auction for five-year contracts and an adjustment auction involving one-year contracts, derived from the main auction's volumes closer to delivery. These auctions are to be led by REE for its firm capacity targets. An essential element of the auction design is the emission limit – stipulated as zero for the new capacities, thus effectively precluding the gas-based capacities and making an opening for battery-based ones.

Spain

Market Developments and Opportunity

In December 2021, the government announced funding support worth €6.9 billion encompassing renewable energy, hydrogen and energy storage. The announcement referred to another €9.45 billion to be sought in private funding for the focus areas. It can be expected that part of the funding could go into the emerging storage technology demonstration or testing projects, as has been the case in several existing utility-scale storage capacities.

The auction-based renewable energy capacity addition could help propel storage growth. In August 2022, the government announced the next bidding round, due in November 2022, for a planned 1.8GW. It will also include bids for hybrid projects (existing or new). Further, unallocated capacity for wind and solar could be transferred to another technology. The announcement of the upcoming auction round also came along with a plan to rationalise gas consumption. This restricts the scope of gas-based capacity in the grid and indirectly strengthens the position of battery-based storage to fulfill similar roles.

The off-grid and self-consumption segment (households and commercial) is emerging as another demand driver for storage. With the rising cost of natural gas, solar power installations are on the rise for captive use. Per the Spanish Photovoltaic Union, solar-based self-consumption capacities rose by over 100% by the end of 2021. As per regulations, residents are allowed to set up 'energy communities' for aggregating the generation from solar PV units. The ongoing boom supports the offtake in battery storage, as many of the installations increasingly come with offers for storage alongside.

Outlook

Officially, Spain's strategy document approved in 2021 refers to a planned 20GW of utility-scale energy storage capacity by 2030, which rises to 30GW by 2050. In addition, the strategy roadmap targets 400MW of behind-the-meter battery storage by 2030. The targets followed Spanish Energy and Climate Plan, which held targets on renewable energy penetration by 2030 and 2050. The policy document shapes a tentative picture of the Spanish energy storage market.

With the rise in renewable energy share, the gap in utility-scale storage capacity will likely entail more significant losses for the power market. One such scenario occurred in April 2022, when the network operator was forced to curtail solar PV generation. The particular incidence of solar power curtailment happened for the first time in the Spanish grid when generation peaked at almost 13.5GW while demand slumped. The solar generators were, as a result, asked to back down. The wholesale power price, at the same time, thus went from €168.5/MWh to €3.70/MWh.

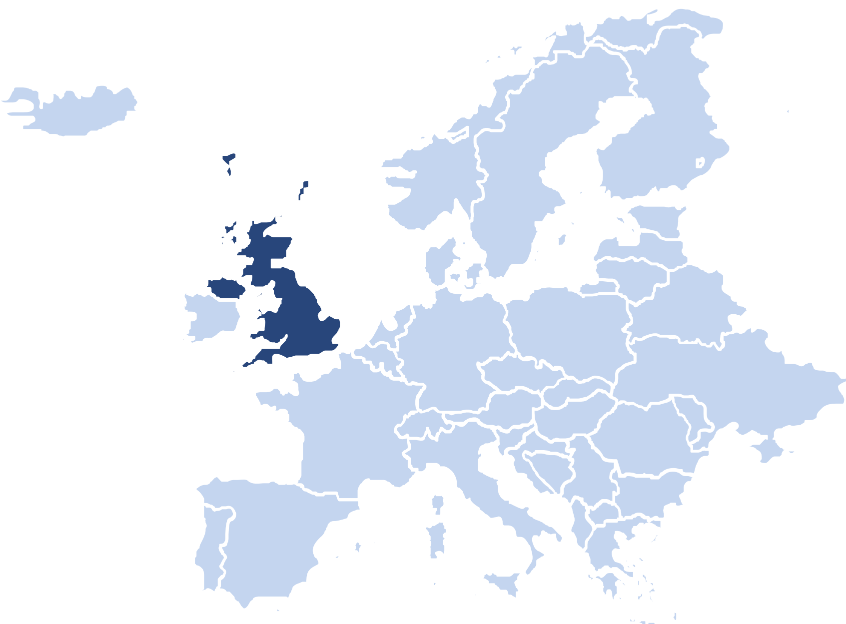
Unlike most renewable energy markets globally, an essential segment of hybrid projects with paired storage capacity is under-utilised in Spain for the same reason. In 2021, the auctions did not yield any storage-linked capacity bids despite the provision. This is because the auction rules held that the storage capacities could be charged only from the linked renewable energy project. Such rules end up inhibiting the storage segment growth that is otherwise critical for several segments of grid management services.

United Kingdom

The UK government has ambitious goals in its energy transition – aiming 95% low-carbon electricity mix by 2030. Among other aspects, this entails a significant expansion in renewable energy resources of wind and solar (besides other energy forms including nuclear and oil/gas). Flexible energy sources, in terms of battery storage, will play an instrumental role in the planned transition. Already, storage assets are increasingly sought for the UK's grid balancing service segment. Demand is rising, as capacity auctions and short-term grid service prices indicate.

GDP (Current Prices) USD (2020)	2,758.87bn
GDP Growth Forecast (constant prices) (2021-2025)	2.85%
Currency	Pound Sterling
Country Credit Rating (S&P)	AA
Energy Storage Capacity* 2021	1,824MW
Renewable Energy Share 2021	38%
Energy Storage Outlook 2030	9.3GW

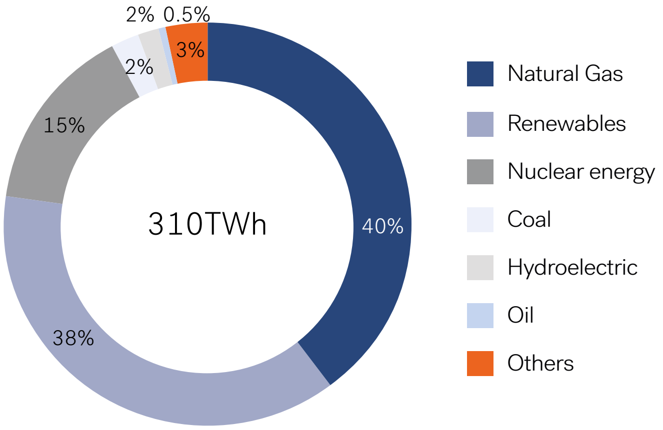
GDP Source: IMF WEO, S&P and IRENA
*Excluding Pumped Hydro



United Kingdom

Energy Mix and Case for Storage

Electricity Generation by Fuel Type (2021)



Source: BP Energy Statistics

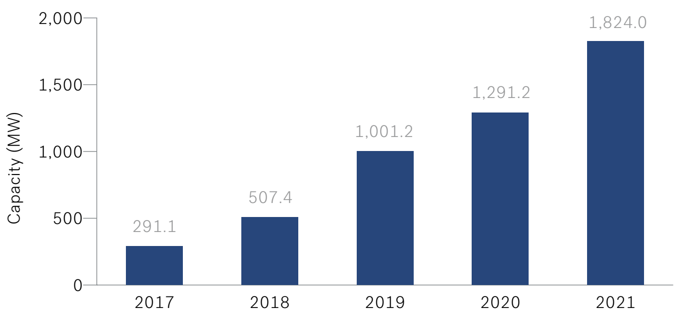
A gradual shift is underway in the UK's power generation fuel mix. The long-term policy objectives of decarbonization and net-zero emissions initially led to the change from coal to natural gas and nuclear. At the same time, renewable energy generation picked up pace in capacity addition. As a result, the power mix currently has renewable sources almost matching the share of natural gas in total energy generation. The planned transition to have a 95% low-carbon electricity system by 2030 is steep, considering the preparedness involved in ensuring network reliability and supply stability. The challenge is compounded by the gas supply crunch imposed by the Russia-Ukraine armed conflict.

In the current backdrop, flexibility in the power generation fuel mix is vital. The government's policy paper on energy security (April 2022) emphasizes this, among other measures, to address the issue of energy security and reliability in emerging dynamics. Battery storage assets, particularly long-duration ones, are crucial in enabling flexible generation assets in the power system. The scope is vast as the existing capacity trend shows that long-duration storage assets are yet to be activated due to challenges in working through various market structures and incentives.

Capacity: Status and Trend

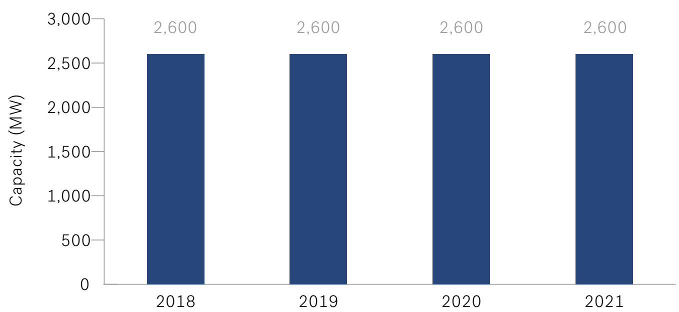
The UK's stationary energy storage capacity (battery-based predominantly) tripled between 2018 and 2021, primarily by the demand for grid balancing services. The need for such assets has been on the rise – it initially picked up the pace with the operator's demand for frequency response support, with the subsequent launch of other grid service segments. Majority of the grid-scale battery storage capacities since 2015 were targeted at the market for primary frequency responses (lasting a few minutes at a time). Since then, the market has been shifting to other ancillary services.

Trend in Aggregate Stationary Storage Capacity



Source: BNEF

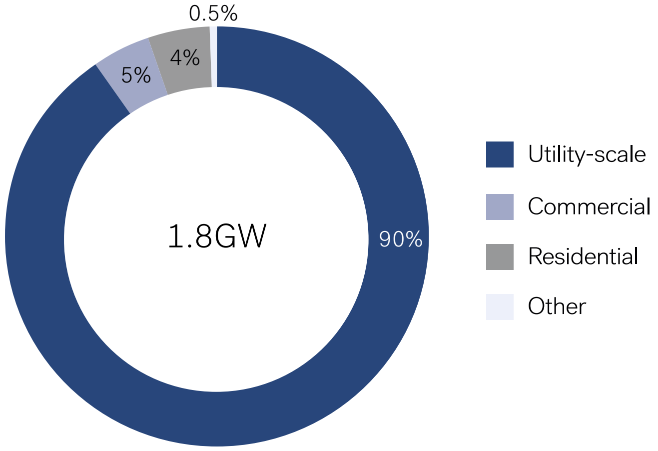
Trend in Pumped Hydro Storage Capacity



Source: IRENA

United Kingdom

Existing Energy Storage Capacity by Broad Segments



Source: BNEF

The utility-scale segment has the predominant share of the UK's stationary energy storage capacity. This is reflective of the importance of grid-balancing service demand. The established technologies continue to be primarily based on Lithium-Ion battery composition, even as other technology combinations are in the fray. Also significant is the gradually rising share of renewable energy projects with co-located batteries. Both being grid-connected serves the purpose of developers and the grid operators in terms of the dispatchabilty of power supply.

Policy and Regulation

In July 2022, the government enacted the amended legislation on Energy (Energy Bill) wherein energy storage was classified as a distinct subset of generation resources. At the same time, the same regulation defines energy storage for clarity among other sources in the energy mix. Such a categorization, however does not help much for energy storage, as the business dynamics are quite different from the typical generation assets. An example is Germany, where the regulatory definition marked storage as a distinct asset class in the energy market.

The policy focus is high on storage due to the anticipated challenges of accommodating the rising renewable energy penetration in the energy network. In the recent past, the steps undertaken to enable storage adoption were part of the measures directed at clean energy resources. For instance, in November 2021, energy storage technologies were exempted (from April 2023 onwards) from the charges that non-domestic (commercial and industrial) properties are liable to pay for local services. As per the policy statement, this exemption will be valid till 2035. During the same period, the government also expanded the scope of contracts-for-difference (CfD) auctions to include those renewable energy projects with storage options attached.

The emphasis is on the long-duration energy storage options (4 hours and above and at least 100MW) due to their maximum potential impact in managing intermittency. In February 2022, the government released funding worth £6 million to help boost the long-duration storage segment. The funding is part of the Department of Business, Energy and Industrial's (BEIS) £68 million funding allocation towards national Net Zero Innovations. As per BEIS, 24 projects received the allocated funding for storage technologies. The projects are meant to be demonstrative of technological and commercial viability. Notably, even though they were eligible, thermal storage technologies could not receive funding.

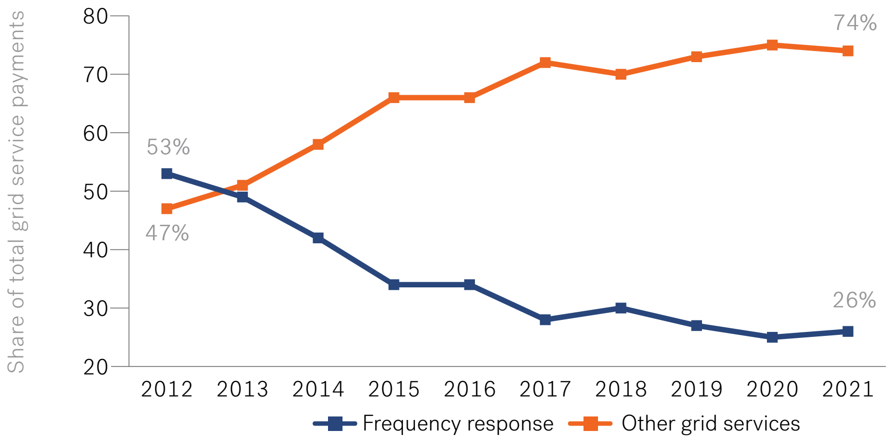
Much more is needed to build the business case for long-duration energy storage projects. As the BEIS reports acknowledge, such projects face entry barriers in terms of the high upfront costs, uncertainty in the revenue streams and weak market signals. Instead, the current market structure is more attuned to the shorter duration flexibility requirement. This is an issue that the policy and regulatory authorities will have to circumvent.

Meanwhile, recent regulatory developments appear to be making favourable progress within the existing frame of shorter-duration storage. The network operator lately introduced other frequency control and management segments that boost storage operators' revenue stack. In April 2022, the network operator launched the first auction of Dynamic Regulation, a pre-fault service designed to correct continuous but short-frequency deviations. In October 2020, the network operator launched Dynamic Containment services. It acted as a major thrust for the battery operators due to the initial high price (£17/MW/h). Significantly, the ambit of Dynamic Containment services was widened to include both low and high-frequency services.

United Kingdom

Market Developments and Opportunity

Trend in the UK's Share of Grid Service Payments



Source: BNEF

In recent years, the UK government's capacity market auctions (to secure power supply against potential blackouts during systemic stress) have emerged as an essential avenue for battery-based capacity. As of February 2022, the UK's T-4 (four-year ahead) capacity market auction cleared at £30.59/kW/year. This was a record-high price for the capacity auctions so far. Most important was the 1GW worth of capacity awarded to battery storage projects. Last year's T-4 capacity for the battery was 800MW. Over 60% of the capacity awarded is for 2-hour battery storage resources. During the same period, the T-1 (year-ahead) auctions saw 385MW of battery storage and 85MW of pumped hydropower.

The power market price arbitrage creates other opportunities for potential storage developers. In the UK market, the dependence on natural gas and limited cross-border interconnection capacity led to upward pressure on the price spreads. Per BNEF estimates, as of April 2022, the average daily min-max spread was €225/MWh. At similar levels of spreads through the year, a one-hour battery storage project could capture the best day-ahead prices every day and meet its revenue target. Yet, the potential revenues captured from arbitrage could be lower than those from frequency response. Furthermore, it is uncertain how long the arbitrage opportunities would last in terms of attractive price spreads.

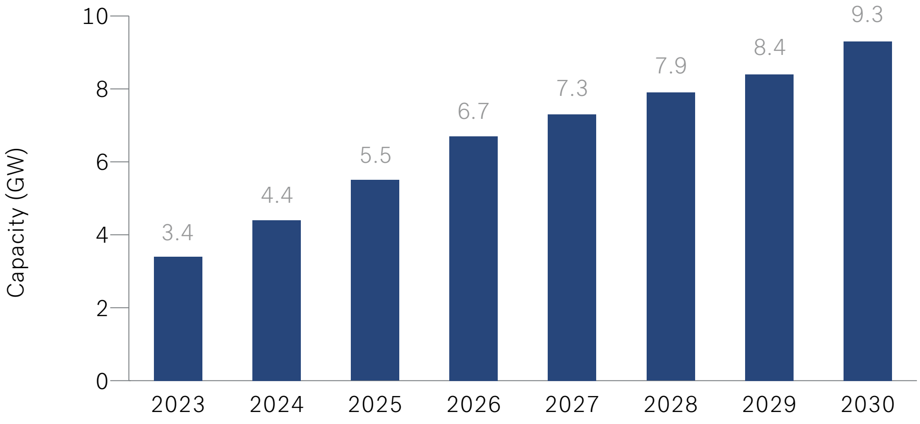
Frequency response services have been the primary revenue-earning source for most storage assets commissioned in recent years. Partly reflecting the recent arbitrage opportunities, the revenue from the frequency response service rose to an all-time high for select energy storage providers. As per the UK's Gore Street Capital, a battery storage developer-investor fund, three of its assets ranked among the highest revenue-earning assets (as of Q4 2021) as frequency response prices rose. In February 2022, the price in this context was reported at a record level of £25/MW/h. Volatility, as an outcome of historically low wind generation output, generation plant outages, interconnection failures and high natural gas prices, all contributed to the overall price determination.

Progressively, the trend shows that grid ancillary services are emerging to play a more significant role in the overall grid-related service revenues. This means grid service elements such as constraint management, reactive power and black-start are rising in proportion to the total grid service payments, while that of frequency response has stagnated. Also, developers stand to gain from early tenders of such services as they get rolled. For instance, in the UK, reactive power services will pay £1 million annually for less than 100MW projects over nine years.

United Kingdom

Outlook

Projected Energy Storage Capacity Addition



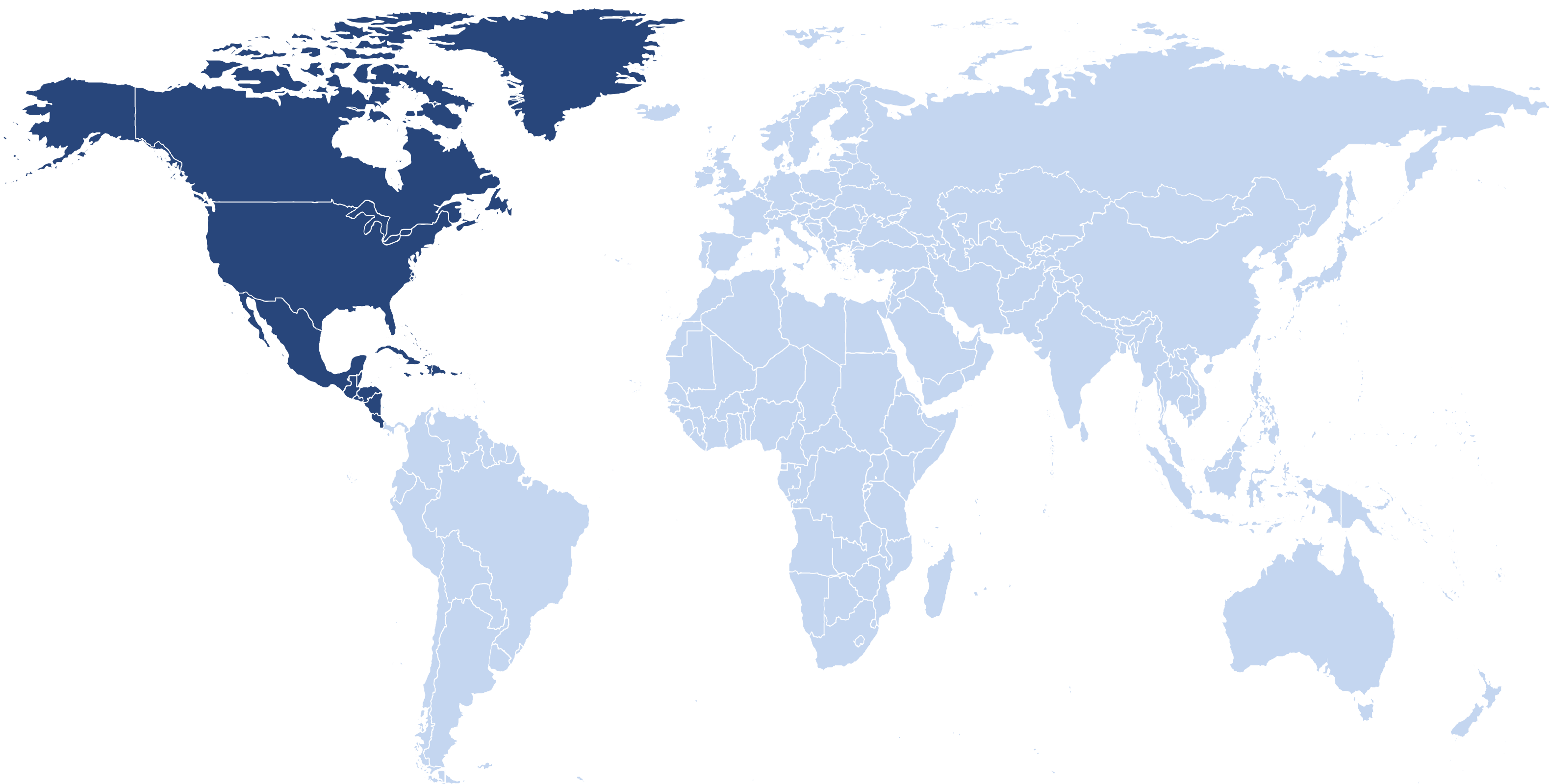
Source: BNEF

As per renewablesUK, the battery storage project pipeline, as of April 2022, reached 32GW – twice that of the previous year. The shift is gradually towards higher unit sizes – helped by enabling policy norms for local authorities to evaluate applications for higher capacity size limits. Hybrid renewable energy projects are part of the pipeline – about one-fifth of the tracked capacity pipeline is from solar power projects with co-located battery storage projects. The investors' interest is thus clearly established for the energy storage market opportunities in the UK.

Progressively, the limits on emission levels (as part of decarbonization and net zero objectives) may act as a catalyst for the battery storage capacity addition. The evidence is found in the UK's capacity auctions market, where gas-based capacities have conventionally skewed the balance. In the recent auction, however, the retirement of gas capacities helped boost the clearing price in the auction. In effect, as the UK transitions to adopt emission norms aligned with EU recommendations, it could result in battery storage clearing the auctions with higher capacity share and an attractive price point. The market design and restructuring will thus be vital to capitalize on the opportunity.

The significant difference in the overall energy storage market and the energy transition framework could come from the long-duration battery storage segment. The barriers are currently too high for prospective investors and developers. Power market reforms are needed at the policy and regulatory levels to set the incentives for long-duration storage providers. Technology is part of the challenges, as many of those in demonstration phases are subject to long lead times and high capital costs. The timeliness in enabling long-duration storage assets in power supply will impact the planned renewable energy-led transition path.

Key Regional Markets - North America



Canada

Canada has set itself a target to achieve a 40-45% reduction in GHG emissions over 2005 by 2030, culminating in net zero emissions by 2050. To achieve this, Canada's decentralized government system would require concerted efforts across all provincial governments. Canada's energy storage market is a marginal one comprising ~130MW of battery energy storage systems ("BESS") and 177MW of pumped storage hydro ("PSH"). But this is likely to change as BNEF projects a cumulative installed capacity of 4.9GW of energy storage by 2030. Canadian Renewable Energy Association (CanREA) has set a target of adding 3.8GW wind and 1.6GW solar annually till 2050 to meet the Net Zero goal. Besides solar and wind, storage has been projected as the third leg of the triad by the Canadian renewables association CanREA, which will help attain this goal.

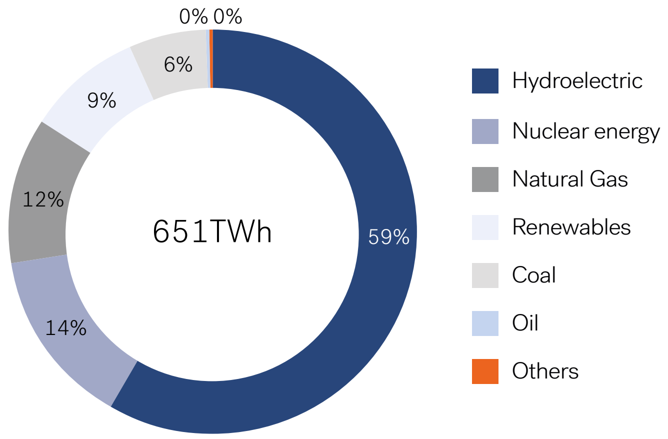
GDP (Current Prices) USD (2021)	1,988.34bn
GDP Growth Forecast (constant prices) (2022-2026)	2.11%
Currency	Canadian Dollar
Country Credit Rating (S&P)	AAA
Energy Storage Capacity* 2021	130MW
Renewable Energy Share 2021	9%
Energy Storage Outlook 2030	4,943MW

GDP Source: IMF WEO, S&P and IRENA
*Excluding Pumped Hydro

Canada

Energy Mix and Case for Storage

Electricity Generation by Fuel Type (2021)



Source: BP Energy Statistics

Hydroelectric power accounts for almost 60% of the electricity generated in Canada. Other non-fossil fuel-based generation sources comprise nuclear and renewable energy, which account for 14% and 9% share, respectively. In terms of installed capacity, renewable hydropower accounted for 80% of the country's renewable installed base of ~103GW in 2021. Hydropower's share of cumulative installed capacity has declined progressively over the years, as wind and solar have primarily accounted for the new incremental capacity being added every year. Canada has been a net exporter of electricity, supplying almost 10% of its overall generation to the United States.

The local electricity grid systems are adequate to absorb the prevailing penetration rate of ~10% for a renewables-based generation. However, a sustained increase in the share of solar and wind-based intermittent generation will necessitate grid balancing and other associated upgrades to integrate the additional capacity coming online.

Unlike European countries, Canada's residential storage market has remained a marginal segment of the overall storage market in the absence of meaningful incentives, poor penetration of rooftop solar, and a fragmented policy approach. Ontario and Alberta are the provinces that have taken the lead in formulating a roadmap to enable legislation that removes barriers to the development of the energy storage market. The commercial and industrial (C&I) segment is a bigger market for energy storage and is projected to account for more than 70% of cumulative storage capacity installed by 2030. The demand for battery energy storage systems (BESS) in Canada's power system has been comparatively muted, given the country's massive hydroelectric reservoirs that offer significant energy storage potential. At 82.6GW, Canada represents the third highest installed hydroelectricity capacity globally, after China and Brazil.

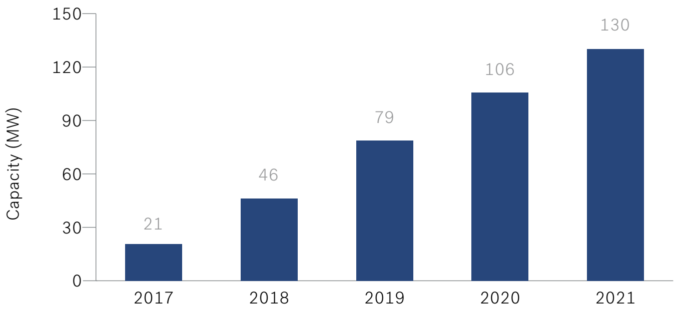
But with a ten-fold jump in renewable generation within the electricity grid, the role of BESS is likely to become more crucial to optimise investments in transmission and distribution infrastructure. A 2020 research study by the National Research Council found that in Ontario, a storage investment would reduce emissions by 11% by 2030. Similarly, a valuation study by Energy Storage Canada and Power Advisory LLC indicated that deploying 1GW storage capacity in Ontario would deliver $2 billion in net savings over the next decade.

Canada

Capacity: Status and Trend

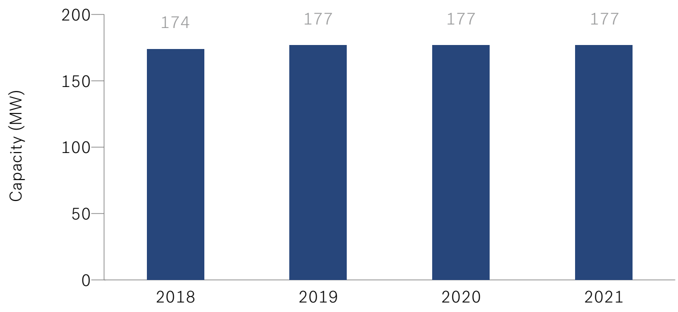
Canada's cumulative energy storage capacity, excluding pumped hydro storage, stood at about 130MW in 2021. While Canada has the third largest installed capacity in renewable hydropower globally at 82.6GW, pumped hydro storage capacity is relatively smaller at 177MW. Canada's lone PSH facility is Ontario Power Generation's Sir Adam Beck Pump Generating Station which provides load-balancing services. Besides, five major PSH projects under development represent a cumulative capacity in excess of 2GW. In the absence of traction in the residential battery storage segment, utility-scale and commercial storage have accounted for a significant share of installed capacity. Alberta and Ontario are the provinces that have been at the forefront of developing the BESS market in Canada.

Trend in Aggregate Stationary Storage Capacity



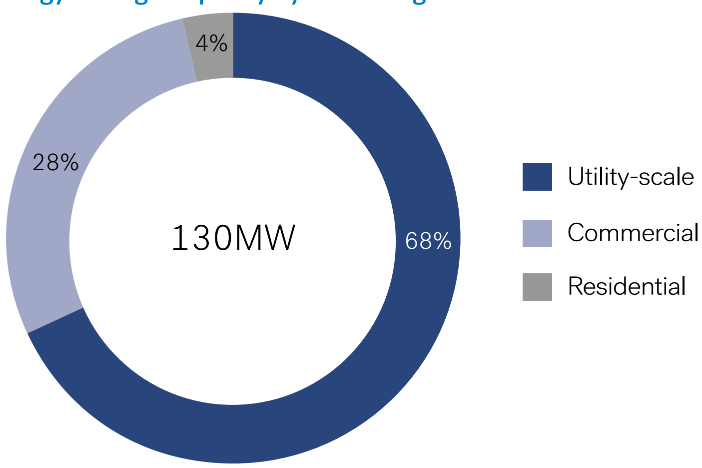
Source: BNEF

Trend in Pumped Hydro Storage Capacity



Source: IRENA

Existing Energy Storage Capacity by Broad Segments



Source: BNEF

CanREA's 2050 Vision document makes a solid pitch for rationalising new investment into transmission and distribution infrastructure by deploying non-wire alternatives such as energy storage and distributed energy resources. Certain provinces like Quebec support these initiatives, such as Hydro-Quebec's energy storage subsidiary EVLO Energy Storage, which has deployed its batteries across multiple applications. Recent examples include a 20MWh BESS that provides backup power for a single transmission line repair and an energy microgrid project comprising solar PV and storage units in downtown Lac-Mégantic. In a recent RFP launched in December 2021 for a 480MW renewable energy project and a 300MW wind project, Hydro-Quebec has specified that energy storage can be combined with the generation units.

Canada

Policy and Regulation

Canada's Federal Budget for 2022 outlines several significant investments to facilitate the energy transition plans and accelerate progress on decarbonization. The allocations include - $250 million over four years for pre-development activities related to clean energy projects; $600 million over seven years for Smart Renewables and Electrification Pathways Program (SERPs); $1 billion over six years to support the recycling of minerals used in the production of batteries and electric vehicles and $900 million to support EV infrastructure. Notably, there is also a commitment to establish an investment tax credit of up to 30% for battery energy storage systems ("BESS") and an additional $458.5 million allocation to the $4.4 billion Greener Homes program to accelerate the installation of rooftop solar PV across Canada.

At a provincial level, Ontario's 'Global Adjustment (GA) electricity charge has been instrumental in driving energy storage installations within the commercial and industrial (C&I) consumer segment. Battery storage offers consumers alternate power sources during peak demand periods, thus optimizing GA charges. Lately, there have been concerted efforts to integrate energy storage within the wholesale electricity market in Ontario. Energy storage was made eligible to participate in the Independent Electricity System Operator's (IESO) "Medium Term RFP" in 2020 to address system reliability requirements. In August 2022, this was expanded to include 2.5GW of new build and existing storage capacity in IESO's latest long-term (LT1) RFPs. While further amendments to the capacity payment mechanism are required to distinguish between the battery and other forms of storage, the inclusion in LT1 procurement plans will provide a fillip to the energy storage sector.

Alberta has been a close second after Ontario in integrating energy storage within its electricity system. Four transmission-connected energy storage projects will be completed by the end of 2021, with an additional 17 in the queue for grid connectivity. Besides several regulatory and legislative changes to integrate energy storage, Alberta's government announced C$25 million in financial support for solar-plus-storage and pumped hydro energy storage as part of a larger C$176 million package that will also give funding to the oil and gas industry.

Market Developments and Opportunity

Advocacy group Energy Storage Canada is pushing for policy initiatives at the federal level to accelerate the development of the energy storage market. However, variations across provincial legislative frameworks regarding energy storage have meant incongruous market growth across different regions in Canada. Ontario and Alberta have taken the lead in clearing regulatory bottlenecks, enabling access to the wholesale electricity market, thereby delivering cost savings to consumers and helping offset expensive capital expenditure on upgrading and expanding transmission and distribution assets. In January 2022, Ontario's IESO was directed through Order in Council O.C. 137/2022 to procure energy from the proposed 250MW Oneida Energy Storage project. Similar procurement contracts for capacity, frequency regulation, power, and operating reserve services are likely to boost revenue streams of storage projects, mitigating project risk.

Behind-the-meter (BTM) storage applications are expected to pick up as incentives linked to the Greener Homes Grant, which offers up to $1,000 in incentives to install batteries. Growth is not restricted to the residential segment alone. The Imperial's Sarna petrochemical complex is developing North America's largest BTM battery storage system owned and operated by Enel X. Its participation in Ontario's demand response program will help establish the feasibility of using distributed energy resources (DERs) in decarbonization initiatives.

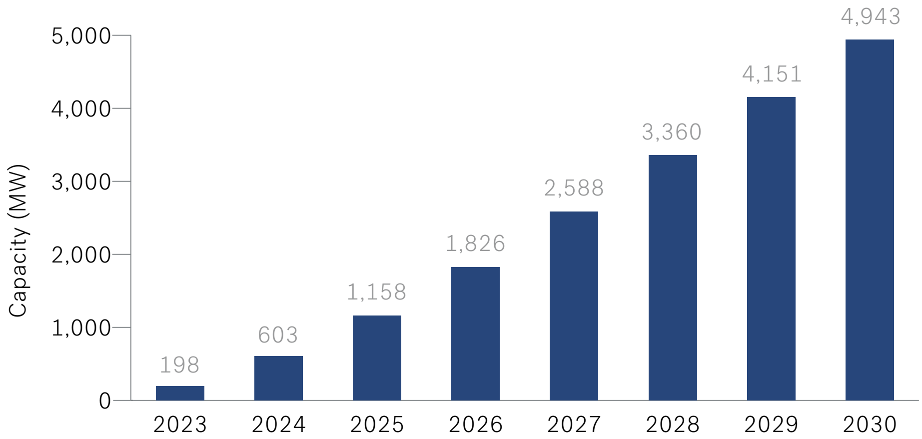
Canada's strength in the battery ecosystem, ranked 4th globally in the lithium-ion battery supply chain, has attracted significant investments. In March 2022, auto-maker Stellantis and L.G. Energy Storage announced their joint venture to invest over CAD 5 billion to establish the country's first large-scale, domestic, electric vehicle battery manufacturing facility. Institutional investors are also making inroads. Canada Pension Plan Investment Board (CPPIB) committed $25 million in investment into Hydrostar, a leading long-duration energy storage solution provider, to develop Advanced Compressed Air Energy Storage ("A-CAES") facilities. This follows Goldman Sachs Asset Management's recently announced $250 million investment into Hydrostar. Public funding support for energy storage has also been available through the Department of Natural Resources or NRCan. Initiatives such as the Charging the Future Challenge, launched in 2019, aim to accelerate battery technology innovations. The governments of Canada and Quebec have also announced investments of CAD 100 million into Lion Electric for the construction of a battery-pack assembly plant. Similarly, the Canada Infrastructure Bank has set a target to invest CAD 2.5 billion over three years into clean power generation, transmission infrastructure and storage.

The energy storage sector's long-term growth depends on access to various services within the electricity grid. This would open up potential revenue streams that would enhance the financial viability of storage assets. CanREA's position paper to promote energy storage identifies 13 service areas, such as capacity, peak shaving, voltage support, frequency regulation, and demand charge reduction, among others. However, existing market structures and payment mechanisms will need to be modified to accommodate the characteristics of energy storage projects to mobilize investment.

Canada

Outlook

Projected Energy Storage Capacity Addition



Source: BNEF

BNEF expects battery energy storage capacity in Canada to scale rapidly from 2023 onwards, reaching ~5GW cumulative capacity by 2030, implying a CAGR of more than 58%. Despite efforts to increase penetration of residential battery storage, projections indicate a marginal role for the residential segment in further development of the energy storage market in Canada unless recommendations such as the 30% Investment Tax Credit (ITC) are adopted. Of the roughly 4.8GW storage capacity expected to be added between 2023 and 2030, the C&I segment accounts for almost 3.5GW, with utility-scale capacity contributing the remaining ~1.4GW. Supporting factors such as declining battery costs, continued deregulation to enable participation in the merchant power market, and new payment mechanisms are likely to drive the adoption of energy storage solutions by C&I prosumers.

The energy storage market in Canada will grow unequivocally on the back of a significant policy push to enable the electricity grid to absorb a ten-fold jump in power generation from renewables. However, Canada is uniquely positioned to choose from multiple energy storage options. Its pre-eminent position as a global leader in hydropower makes it ideal to consider pumped storage hydro as an alternative. Besides BESS, Canada has been at the forefront of technological innovation in compressed air energy storage (CAES). Access to natural minerals and having a mature battery ecosystem will be vital for developing and expanding the BESS market. However, the sustained investment will require further deregulation, accompanied by new market structures, procurement, and valuation methods that enable revenue stacking and offset the financial risks of storage projects.

Mexico

Mexico's energy transition plans have been embroiled in political uncertainty since President Andrés Manuel López Obrador's (AMLO) administration came to power in 2018. The current regime's stance on renewable energy has been highlighted by a slowdown in energy transition initiatives, efforts to nationalize the country's power sector, and progressively increasing support for fossil fuels. This marked a sharp reversal over the previous regime's aggressive decarbonization actions, resulting in massive renewable energy capacities contracted out in auctions delivering the lowest global solar and wind prices. In 2021, following a judicial intervention, Mexico's 2020 update on its NDC (Nationally Determined Contribution) was replaced by its original 2016 climate goals. A lack of Net Zero target underscores the tepid support for renewables within the incumbent administration.

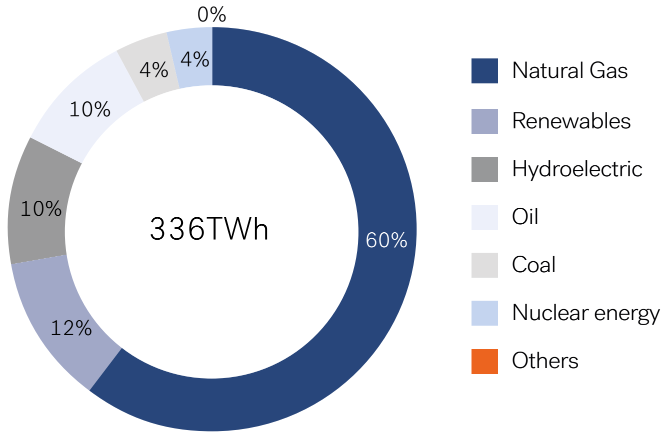
GDP (Current Prices) USD (2021)	1,297.66bn
GDP Growth Forecast (constant prices) (2022-2026)	1.86%
Currency	Mexican peso
Country Credit Rating (S&P)	BBB
Energy Storage Capacity* 2021	28MW
Renewable Energy Share 2021	12%
Energy Storage Outlook 2030	1,305MW

GDP Source: IMF WEO, S&P and IRENA
*Excluding Pumped Hydro

Mexico

Energy Mix and Case for Storage

Electricity Generation by Fuel Type (2021)



Source: BP Energy Statistics

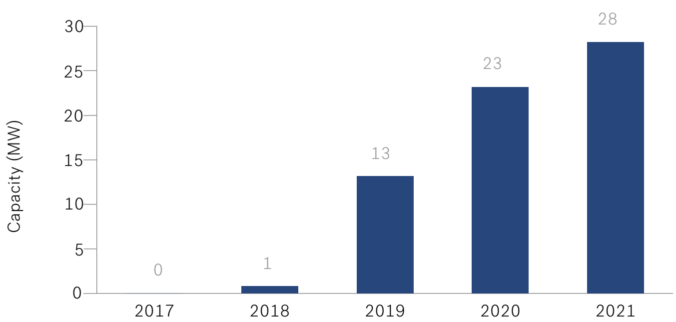
Almost 60% of Mexico's power generation is gas-based, with renewables and hydroelectric power constituting ~22% share cumulatively. In terms of installed capacity, renewables accounted for 32.6% in 2021, up from 27.6% in 2018. Hydropower accounted for the highest share of installed capacity among renewable energy technologies at 12.7GW in 2021, equating to ~43% of aggregate renewables installed capacity of 29GW, followed by wind (7.7GW) and solar (7.0GW). Mexico has ceded its leadership position as a pre-eminent global destination for renewables investment since the change in government in 2018. A series of policy reversals, including a reversion to fossil fuels and a proposal to roll back foreign investment in Mexico's energy industry, has worked to dampen investor enthusiasm.

However, the defeat of the Energy Reform Bill in the Mexican Congress in April 2022 has indicated that there is still widespread political support for expanding the role of renewable energy in the country's power sector. Estimates from IRENA suggest that Mexico has the potential to have 30GW of installed capacity for solar and wind by 2030. With an increased share of renewables-based power generation, the need for an energy storage infrastructure has never been so acute. The discovery of massive lithium deposits in the country bodes well for developing a battery-based energy storage market. Still, the market structure has to evolve to attract private capital, away from a state-run extraction approach.

Capacity: Status and Trend

The market for energy storage in Mexico is marginal, with cumulative energy storage capacity, excluding pumped hydro storage, equating to ~28MW in 2021. Most of the installed capacity is utility-scale and deployed in energy shifting. There is a minuscule energy storage market for the commercial and industrial (C&I) segment. Notably, the first grid-scale battery in Mexico was installed at an automotive factory in Monterrey in 2018. The 12MW installation was tasked to provide spinning reserve, voltage support and frequency regulation to a 130MW industrial microgrid serving the industrial campus. There seems to be a strong case for sustained penetration of energy storage within the C&I segment, particularly as behind-the-meter installations offer scope to rationalise capacity charges, which constitute almost 25-30% of the electricity bill, through peak shaving.

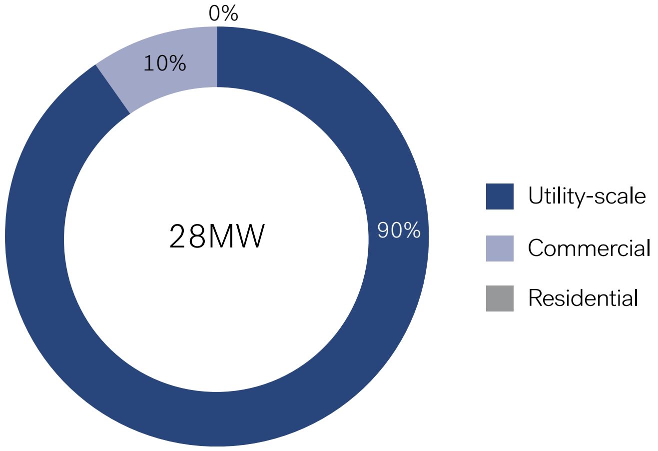
Trend in Aggregate Stationary Storage Capacity



Source: BNEF

Mexico

Existing Energy Storage Capacity by Broad Segments



Source: BNEF

While the battery storage market is still nascent, the increased proliferation of renewable energy sources in Mexico's power generation base creates a compelling case for developing the energy storage market. The most significant push is from hybrid plants incorporating solar and storage elements. The market is rapidly expanding, with an estimated 300 hybrid systems coming online since the start of 2020. Hydropower, representing the highest installed capacity (12.7GW) among clean energy sources, has remained static in the face of opposition from local communities and public skepticism regarding large hydropower projects. IRENA anticipates a pick-up in small hydro projects, equating to 90MW capacity addition till 2030, besides a resumption in hydropower capacity building leading to 26GW installed capacity by 2030. Notably, there is no pumped storage hydro (PSH) capacity in Mexico despite a significant installed base of hydropower.

Policy and Regulation

The energy storage sector in Mexico is currently unregulated, with no specific laws defining it or governing its use. It is generally regarded as a limited source of energy generation that must adhere to some requirements to inject power into the grid for a short duration. While there are no specific incentives for energy storage, it is presumed that its classification as a source of energy generation would make it eligible for the same incentives offered to renewable energy. In this case, projects are offered accelerated depreciation for tax purposes. In the absence of a legal definition of energy storage and ambiguous market regulations, the development of the industry has been stunted. While there are isolated large battery installations in the country, the regulatory uncertainty and the perceived absence of a policy push have worked to deter any substantial investment in the sector, either domestic or foreign. The nationalization of the considerable lithium deposits in the country in April 2022 added to the uncertainty within the private sector.

Regulatory changes, introduced in May 2020, have skewed the power market in favour of the state-owned utility CFE (Comisión Federal de Electricidad). Most detrimental among all changes were the curtailed open access to private market participants and arbitrary methods of evaluating interconnection requests. The new policy also authorizes new ancillary services for the grid's stability and safety, in addition to existing services that already receive remuneration, such as reactive reserve, reactive power and grid re-energization. Energy storage is likely to be commercialized as an ancillary service under the wholesale electricity market, with frequency response and regulation as the key focus.

Market Developments and Opportunity

The behind-the-meter (BTM) C&I segment will likely be the driver of growth for energy storage in Mexico in the short term. Adverse legislative changes have made it harder to trade energy on the wholesale market, thus stymying the development of utility-scale energy storage. Mexico's substantial base of industrial facilities presents a significant scope to deploy battery energy storage systems (BESS) in industrial microgrids. Such deployment can enable industrial consumers to secure reliable power supply and optimise consumption curves, delivering 20-40% savings on electricity costs by avoiding peak hour tariffs. This is evident from the major battery installations in Mexico that the C&I segment has primarily commissioned. Recent examples are a 25MWh BESS that system integrator Quartux will install at a hotel site in Mexico and a 3.2MWh order from Revolve Renewable Power Corp for a battery storage unit at another hotel chain. The former is purported to be the largest battery installation in Mexico and the largest C&I project in Latin America.

The absence of policy support and associated incentives has also led to the development of innovative business propositions.

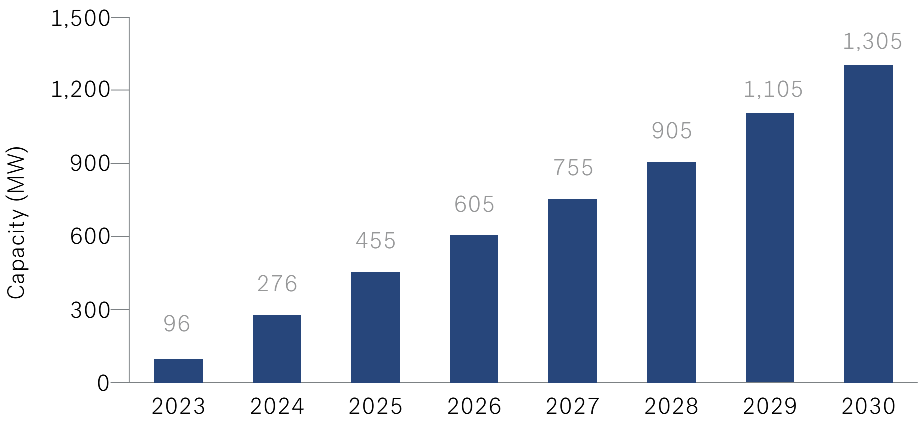
One example is the energy storage-as-a-service business of Fotowatio Renewable Ventures (FRV), US-based energy analytics and software company Energy Toolbase and local developer Ecopulse. This business model was first introduced to the market by Quartux in 2017. Consumers are not required to make upfront capital expenditures on installation. Instead, the project partners will be paid by sharing the electricity savings in a model similar to what Stem Inc and Enel X have offered C&I customers with access to energy savings via battery storage in the US and Canada. The first installation under this model will be a 480kW two-hour Li-ion BESS in the Mexican industrial region of Iztapalapa.

The possibility of developing the domestic energy storage supply chain offers an additional upside potential to the market. While the nationalization of lithium resources has added an element of uncertainty, broader global efforts to pivot away from a China-centric battery supply chain in favour of nearshoring is likely to benefit Mexico. Global battery manufacturing major CATL has been reported to be scouting for sites in Mexico to establish what can be Latin America's first Li-ion cell battery gigafactory. The leading battery storage system integrator Powin had already shifted its assembly plant to Monterrey.

Hybrid renewable energy plants, particularly solar-cum-storage installations, constitute another significant growth driver for energy storage in Mexico. Latin America's first utility-scale solar plus storage project was Aura Solar III, located in Baja California Sur, commissioned in 2019. It has a generation capacity of 32MW paired with a 10.5MW Li-ion BESS. Wind energy projects have also started incorporating storage elements, as evidenced by the 50MW Eolica Coromuel wind farm under construction having a 10MW BESS onsite, supplied by Wärtsilä.

Outlook

Projected Energy Storage Capacity Addition



Source: BNEF

The projections indicate sustained growth in Mexico's energy storage market, with cumulative installed capacity expanding to 1.3GW by 2030. Annual capacity addition could average 173MW between 2023 and 2030. Projected growth is primarily because of the market demand as the share of solar and wind energy in Mexico's power generation base expands significantly. With IRENA estimating a potential of 60GW solar and wind installed capacity by 2030, this decade is likely to witness capacity addition that is more than thrice the existing installed base, thus heightening the need for energy storage to balance the grid. Distributed generation is likely to be a key enabler for energy storage, as evident from the C&I segment's share of ~39% of the country's storage installed capacity by 2030. Utility-scale deployments in an energy-shifting role will account for ~57% of the cumulative installed capacity by 2030.

The lack of a concerted policy push and supportive regulatory environment continues to be an overhang on the growth potential of the energy storage sector in Mexico. A holistic approach requiring the involvement of research institutions, policymakers and financial institutions will be needed to develop a mechanism to make storage projects financially feasible. Lack of clarity on financial returns remains a crucial challenge to widespread adoption and investment since remuneration mechanisms on possible revenue streams are absent.

Recent policy changes have also been detrimental to the development of renewables and, subsequently, the energy storage sector. The amendment to transfer control to the CFE (Comisión Federal de Electricidad), which presently owns 54% of the power market, has enabled it to prioritise its power generation from hydro, nuclear, natural gas and oil, irrespective of the power prices. Renewables-based generation, primarily the domain of the private sector, will have lower priority in dispatch, thus making it less attractive for private sector investment. However, the long-term growth potential of the energy storage market remains robust to enable the transition to renewable energy sources.

United States

The US energy storage market is the world's largest and is poised for outsized growth to support the influx of renewable energy generation. Critical systemic requirements such as network reliability, capacity planning and clean power procurement are setting the pace of change in the US energy storage market. Hybrid renewable energy projects involving co-located storage systems have emerged as a growth driver in grid-scale storage capacity. At the same time, price fluctuations in the grid (due to expensive natural gas or retirement of old capacities) make a strong case for merchant-based storage capacities. The market is thus getting significant attention from all stakeholders for potential business opportunities.

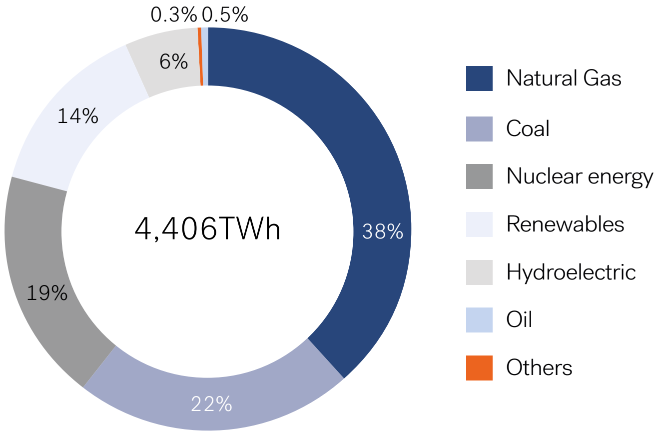
GDP (Current Prices) USD (2021)	22,996.08bn
GDP Growth Forecast (constant prices) (2022-2026)	1.53%
Currency	US Dollar
Country Credit Rating (S&P)	AA+
Energy Storage Capacity* 2021	6,840MW
Renewable Energy Share 2021	14%
Energy Storage Outlook 2030	91.7GW

GDP Source: IMF WEO, S&P and IRENA
*Excluding Pumped Hydro

United States

Energy Mix and Case for Storage

Electricity Generation by Fuel Type (2021)



Source: BP Energy Statistics

The rise in renewable energy-based power generation drives the US power generation mix shift. Even as natural gas holds the maximum share of existing total generation, it is already outpaced by renewable (wind and solar) energy in terms of annual capacity addition. The US Energy Information Administration's (EIA) latest report shows that since 2019 developers have added more non-hydro renewable energy capacity than gas-based ones. Incremental capacity in the grid is primarily led by utility-scale solar photovoltaic power.

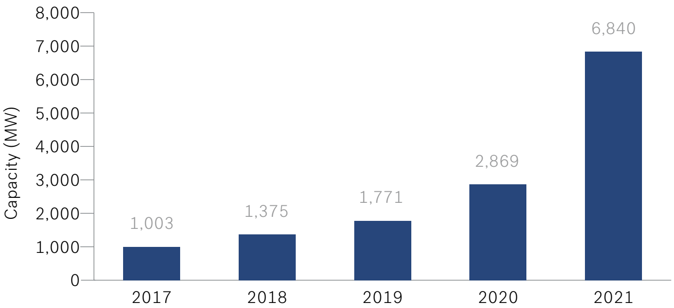
The projected and imminent rise in renewable energy share will also run in parallel to a phased retirement of coal-based power generation assets and a markedly reduced share of natural gas. EIA's estimates show that 12.6GW of coal-fired generation is due for retirement by the end of 2022. Another 1.2GW will be from gas-based plants in the same year. Over 23GW of coal capacity could be offline by 2028. This implies pressure on the network to accommodate intermittent generation with a receding share of baseload supply options. Added pressure comes with the stated policy objective to achieve a net-zero emission economy by 2050, for which a 50%-52% reduction in greenhouse gas pollution is aimed by 2030.

Grid-scale energy storage increasingly has a strong business case in the US. The most prominent example is the rise in hybrid renewable energy projects, with battery-based storage co-located with the generation project (primarily solar). At the same time, grid management challenges are making network operators consider enabling norms for storage developers, such as by including norms for storage-based energy as participants in the wholesale power market transactions.

Capacity: Status and Trend

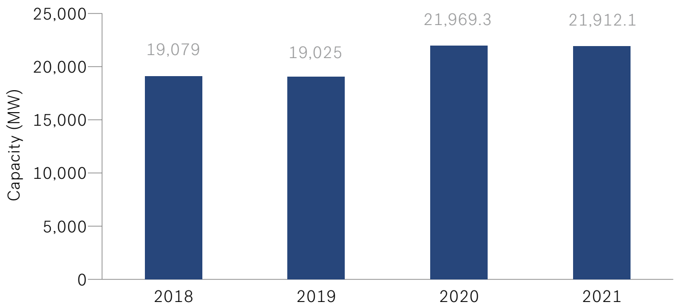
By the end of 2021, the US installed energy storage capacity had almost quadrupled over the previous year's level. The battery storage added this year was the highest ever. The capacity addition achieved reflects the rising integration of batteries in the grid-connected power, whether through the co-located hybrid wind/solar generation projects or the grid operators' measures at shifting options from the conventional gas-based peaking power projects deployed in grid management/stabilization roles. The installed capacity in 2021, as per S&P Global's tracked data, predominantly comprised 2-4 hours' storage capacities based on the Lithium-Ion technology configuration.

Trend in Aggregate Stationary Storage Capacity



Source: BNEF

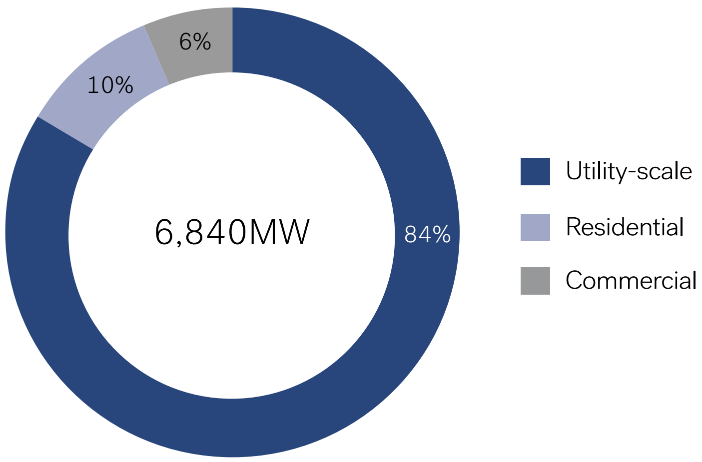
Trend in Pumped Hydro Storage Capacity



Source: IRENA

United States

Existing Energy Storage Capacity by Broad Segments



Source: BNEF

In a regional context, California and Texas hold the maximum share of the US energy storage market. Part of the reason for such a leadership position is the regulatory framework in the respective states, both for renewable energy and storage assets. The state of California was among the pioneering ones to enact enabling norms to integrate energy storage in the bulk power market. The state also leads in terms of renewable energy share in the total power supply and the emission norms of power.

The total installed storage capacity is thus skewed towards the utility-scale segment. This will likely be this way, as grid management is the primary demand driver in the US storage market. Notably, the grid services segment is gradually poised to expand as network operators consider changing the market structure for battery storage options. The competitive cost of batteries against the competing options in conventional fuels (mostly natural gas) is another supporting factor in the emerging scenario. In contrast, the growth in residential and commercial segments depends on volumes. Residential and commercial solar units are the key avenues for the deployment of batteries (both grid-connected and off-grid).

Policy and Regulation

The policy-level enablers for battery storage systems are found in different segments of governance. At the federal level, the most notable and recent one is the Inflation Reduction Act of 2022. Its critical provision is the long-term extension of the Investment Tax Credit. While targeted at the solar industry, it applies to energy storage in co-located and standalone modes. The legislation offers a 10-year extension at 30% of equipment cost. By 2033, the available credit will be scaled down to 26%, and 22% in 2034. For developers or project owners, it is also noteworthy that this regulation allows for the retrofit of the existing solar generation units with batteries while availing the tax credit.

Separately, funding is made available under different schemes to promote ongoing battery technology initiatives. For instance, funding allocated under the Better Energy Storage Technology Act supports research, planning and pilot projects. In May 2022, the US federal government's Department of Energy announced plans to set up a $505 million Long Duration Energy Storage initiative. It will focus on the demonstration, validation and piloting of critical technologies related to grid-scale long-duration storage.

A much more substantive contribution lies with the network regulators – comprising regional transmission organizations (RTO) and independent system operators (ISO), and the overarching guidance from Federal Electricity Regulatory Commission (FERC). In its 2018 order, for instance, FERC directed all the RTOs and ISOs to ensure an updated tariff structure that recognizes the specific energy storage characteristics for market participation. Since then, progress has been varied, subject to local conditions. For instance, in September 2022, the Midcontinent Independent System Operator (MISO) included energy storage for the first time in its market portfolio.

Distributed energy resource participation is another vital segment poised for expansion with FERC's regulatory directions. In its order of September 2020, FERC asked all the authorities to remove barriers to the participation of distributed energy resources for electrical energy, capacity, and ancillary services in the wholesale power markets. The full implementation of this could be a long-drawn process. California and New York's ISOs have already met this, while others sought extension or are in the roll-out process. In New York, the operator aims to enable aggregations of distributed storage systems to earn compensation based on market participation by the end of 2022. Once implemented, FERC's order will allow the standalone distributed energy storage units (including storage resources such as battery-based electric vehicles) to inject energy into the grid like other market participants.

United States

Market Developments and Opportunity

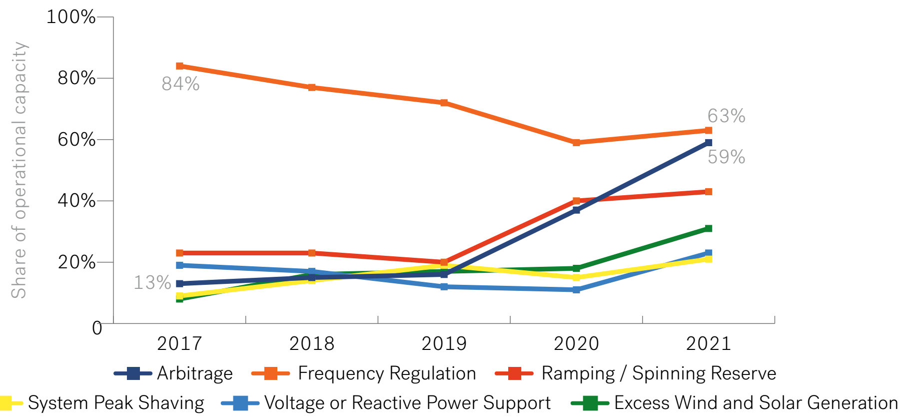
The scope of grid-scale energy storage systems has progressively expanded, driven partly by the rise in renewable energy penetration and the resulting measures by the ISOs and RTOs. The Californian power system is a prominent example. It has had a strong deployment momentum as battery storage systems have been actively utilized to manage both capacity shortfall and renewable energy volatility. The California Public Utilities Commission's norms on power procurement (for network reliability) during 2023-2026 reinforced the case for battery storage. Clean energy mandates and relatively expensive gas-based power tip the balance in favour of batteries in the case of California's power procurement framework.

The power market continues to shape battery demand in other ISO areas. The Electric Reliability Council of Texas (ERCOT) faces a relatively high share of wind and solar energy in its grid supply than other ISOs. Unlike others, though, ERCOT operates an energy-only wholesale power market (generators pay for day-to-day supply). Developers are thus keen to tap into the battery storage demand in real-time energy and the ancillary service segments. The ERCOT region has a high solar buildout (28GW solar with signed interconnection agreements) that will invariably require battery energy support. It also does not help that just a small part of ERCOT's upcoming solar capacity is paired with co-located battery storage – indicating the scope of requisitioning grid support services from developers.

As of 2021, frequency regulation and price arbitrage stood out as the top two application areas of utility-scale battery storage deployment. Most battery storage units are typically deployed for more than one application area or grid service. While frequency regulation has been the most common application, the trend shows a rising share of battery capacity used in price arbitrage. In contrast, the frequency response role declined in relative share, indicating a possible saturation. Select network operators have reported a significantly high share of batteries in the price arbitrage role. The California Independent System Operator (CAISO) service territory had over 80% of operational battery storage devoted to price arbitrage in 2021.

The same EIA data also confirms the rising importance of hybrid renewable projects – 93% of the battery capacity commissioned in 2021 is from the storage units co-located with utility-scale solar power projects. The same is valid for the capacity under development. About 60% of the planned battery storage capacity for 2023 is co-located with power generation capacity, predominantly solar power. The project pipeline in California ISO and PJM Interconnection is notable for the solar projects combined with battery storage systems.

Trend in the Application of Utility-scale Battery Storage Systems



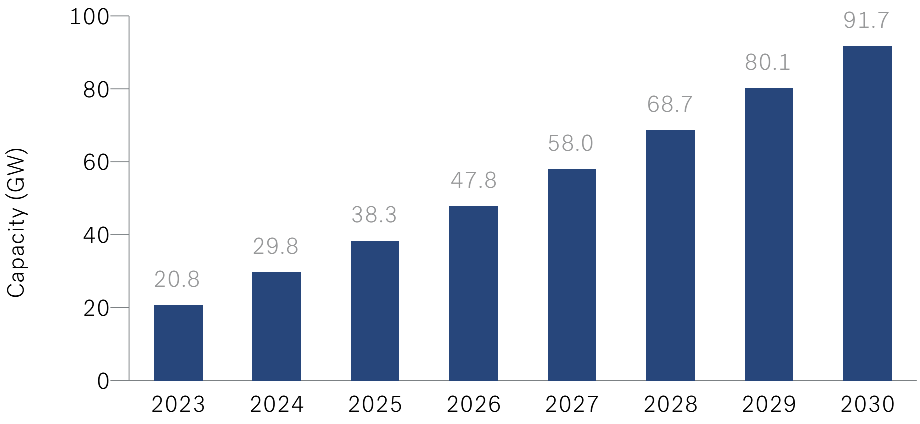
Note: (a) Data represents a select set of applications among others reported in EIA publication. (b) Grid-scale battery systems are typically deployed for more than one application.
Source: EIA Annual Generation Reports (respective years)

Notably, the behind-the-meter battery storage segment also shows significant encouraging signs of growth. As per Wood Mackenzie's estimates, Q1 2022 was the strongest, with 334MWh worth of residential storage capacity across 20,000 installations. Persistent supply challenges (trade restrictions and supply chain issues) hindered growth in this segment. Many behind-the-meter installations thus continue to be based only on solar, devoid of battery storage. This is a segment that is poised to rise manifold.

United States

Outlook

Projected Energy Storage Capacity



Source: BNEF

The US energy storage capacity pipeline is led by the upcoming renewable energy (predominantly solar) capacities. The capacity in the queue for interconnection at the respective ISOs is one indicator to gauge the projected growth (not everyone is equally likely to connect or commission). As of 2021, 1TW worth of renewable capacity and 427GW of storage capacity were registered in the queue for the interconnection request at ISOs (Lawrence Berkeley report estimate). There is, thus, a strong likelihood of a spike in energy storage capacities, both as standalone and paired systems.

The inflationary pressure in the economy and the resulting rise in commodity prices has led to higher battery storage systems costs. Suppliers point to higher costs of battery metals (such as Lithium Carbonate) and logistics which must be passed on to the developers. BNEF's survey data with battery manufacturers $show that the turnkey system price for a 4-hour storage unit due for 2023 ranges between $250 kWh and $400/kWh, which is significantly higher than the previous year's comparable survey on the same. While some developers have renegotiated the prices, others have chosen to defer till prices stabilize. The renegotiation is more likely for merchant projects as they are not tied under utility contracts and thus face lesser regulatory scrutiny on pricing.

The provision of timely interconnection continues to be a systemic issue in the industry. This will impact the commercials for energy storage projects. PJM, for instance, is the largest ISO operation area in the US and its regional market is poised to become in US storage capacity. But PJM interconnection continues to be a bottleneck, delaying the storage capacity deployment. As of March 2022, there were 19.4GW of active late-stage storage projects in PJM's New Services Queue.

The energy storage potential is untapped mainly due to the lack of conducive market design and operation. It will be a gradual process for regulators and operators, as FERC recently held. Most critical questions are still to be addressed in terms of defining the energy storage capacity role in the power market (such as during peak versus off-peak loads) and identifying the multiple grid services for value-stacking storage capacities brought onstream. The regulatory authorities will have to match the industry's dynamic growth path to meet the desired objectives.

Key Regional Markets - South America

Brazil

Brazil's nascent energy storage market is emerging as an anomaly against the rapidly growing renewable energy sector. Due to distributed generation projects, most of the installed storage capacity is led by commercial and industrial entities. Utility-scale storage is negligible, as the power market norms are yet to be defined. In this regard, some of the upcoming projects could hopefully mark a shift in the trend followed so far.

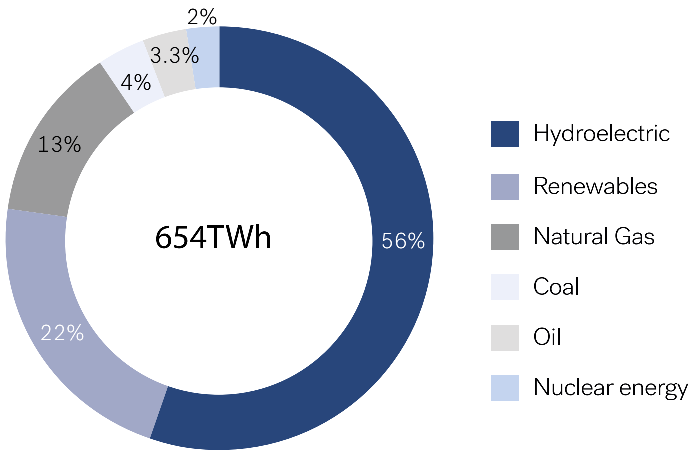
GDP (Current Prices) USD (2021)	1,608.08bn
GDP Growth Forecast (constant prices) (2022-2026)	1.94%
Currency	Brazilian Real
Country Credit Rating (S&P)	BB-
Energy Storage Capacity* 2021	13.1MW
Renewable Energy Share 2021	22%
Energy Storage Outlook 2030	4,286MW

GDP Source: IMF WEO, S&P and IRENA
*Excluding Pumped Hydro

Brazil

Energy Mix and Case for Storage

Electricity Generation by Fuel Type (2021)



Source: BP Energy Statistics

Brazil's energy mix is notable for the predominant role of hydropower generation. As per IEA, clean energy resources meet 45% of Brazil's primary energy demand, making the country's energy sector among the least carbon-intensive globally. In such a scenario, Brazil's energy transition is about shifting the balance to renewable energy – implying wind and solar, both of which are largely untapped in potential.

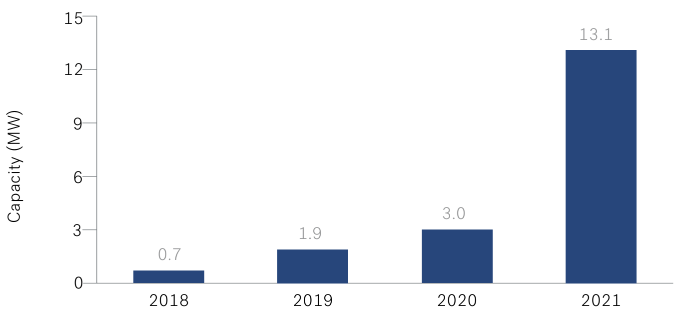
The auction-led capacity allocations indicate a steady renewable energy project pipeline rise. With the rising share of renewable generation in the grid, the displacement of conventional generation is imminent. Although a protracted process in local circumstances (subsidized coal-fired power plants are allowed till 2040), the phaseout of fossil fuel generation cannot be pushed back indefinitely. The grid operator's capacity planning suggests a potential $4 billion required investment in the power network to integrate the projected generation.

While the investment estimates suggest the growth roadmap, the transmission infrastructure has lagged behind the growth in power generation capacities. Grid connectivity is lately emerging as a bottleneck for upcoming projects, as seen in the relatively muted response to the recent auctions. While transmission capacities catch up, energy storage solutions will be the vital component of network management as intermittent renewable energy rises in share. Even with hydro power resources abound, the case for battery-based storage strengthens each day due to its multiple functionalities in grid management.

Capacity: Status and Trend

Brazil's energy storage capacity growth trend derives predominantly from the progress achieved in solar PV-based distributed generation. Policy and regulatory focus on distributed generation ensured that battery growth picked up alongside. Conventionally lead-acid battery systems have been used for small off-grid generation systems. In commercial applications involving relatively higher capacity, off-grid applications have had hybrids such as solar-diesel-battery combinations gaining currency due to the benefits in both costs and emissions. Such applications are also deployed in isolated communities and rural/agricultural consumer segments.

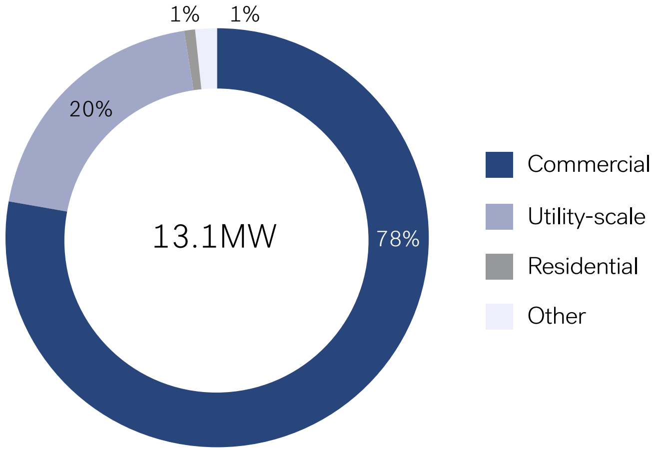
Trend in Aggregate Stationary Storage Capacity



Source: BNEF

Brazil

Existing Energy Storage Capacity by Broad Segments



Source: BNEF

Utility-scale energy storage segment is yet to take off in Brazil. This is due to the lack of a regulatory framework defining the incentives and requirements. The existing capacity base is thus a mix of research and development, technology demonstration, or hybrid co-located units. Co-location of the battery units is a relatively stronger option. The transmission company CTEEP's upcoming 30MW battery storage project is among the most critical projects. It is due for commissioning in 2022 and could change the utility-scale storage landscape.

Policy and Regulation

Brazil's policy and regulatory structure did not prioritize the energy storage segment for a long time. Such a position could be partly due to a predominant hydropower-skewed power system. While the scenario has changed drastically with the rise in renewable energy, policy and regulatory response continues to lag. Utility-scale energy storage, critical for grid management, is thus mostly neglected. In November 2021, the regulator approved the country's first grid-scale battery storage project.

Though indirect, yet regulator's recent norms for the distributed generation segment could help the case for battery storage. In January 2022, revised rules on distributed generation provide for including all such capacities under the net metering regime from 2023 onwards. It makes solar PV-based prosumers (injecting net surplus generation back to the grid) more amenable to battery storage. In the previous regime, such capacities would have had to pay fees to inject excess energy into the grid.

The regulator-approved pilot projects on energy storage, under a program launched in 2016, are still under development and are expected to be commissioned by the end of 2022. There are 23 such projects, which include various storage technologies besides Lithium-Ion, to establish feasibility. The results from these projects could shape the regulations on grid-scale storage.

Market Developments and Opportunity

Although slow in taking off, utility-scale storage projects are gradually finding traction. One such storage 30MW project is currently under development which the regulator approved in 2021. The project is led by the transmission company ISA Cteep which entered into contracts with You.On Energia and TS Infraestrutura. The $146 million project is expected to be commissioned by the end of 2022.

The country's utility-scale solar PV project pipeline could be an essential demand driver in grid-scale energy storage. This is because hybrid projects involving solar-plus-storage configurations are gradually coming to the fore. One proximate reason is that lack of timely grid connectivity could reinforce the case for linked-storage systems.

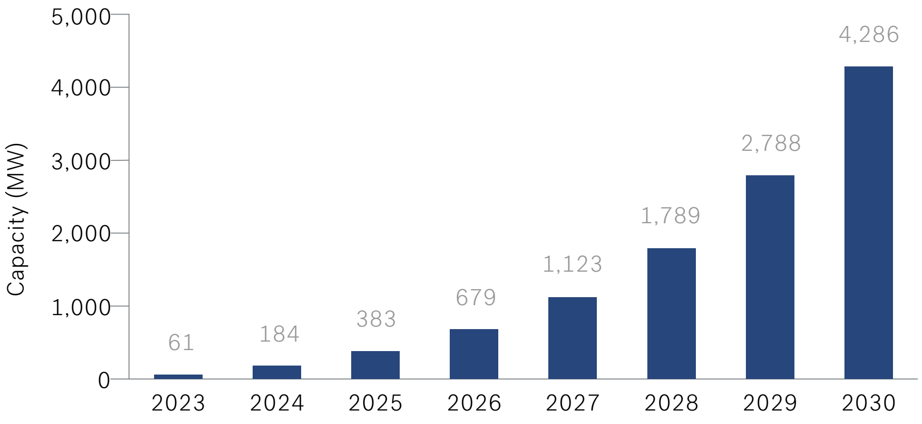
Pilot projects are underway to establish the techno-economic feasibility of the new storage technologies. One recent example is a 1MWh thermal energy storage project by an Israel-based company Brenmiller Energy. It is a pioneering project in the region to deploy renewable-based (biomass in this case) thermal energy stored in crushed rocks for subsequent use in manufacturing as a process-heat application. The system can also discharge electricity based on a steam turbine.

Brazil's off-grid energy storage presents more significant opportunities in the near term than the utility-scale segment. Battery-based energy is a competitive option in several Brazilian states due to the massive difference between peak and off-peak tariffs. As per a study by consulting entity Greener (as of July 2022), for a typical commercial/industrial consumer, the state of Rio Grande do Norte's difference between peak and off-peak tariff stood at $R3.004/MWh. As analyzed in the study, battery storage translated to 36% savings on the tariff.

Brazil

Outlook

Projected Energy Storage Capacity



Source: BNEF

Despite muted growth, Brazil's energy storage outlook indicates high growth prospects. The utility-scale segment could find the maximum thrust of growth and investments. The capacity pipeline is expected to gradually expand as crucial projects such as the CTEEP's and the regulator-approved technology demonstration projects come online. Notably, the commissioning of the CTEEP project can help establish the use case of ancillary services for which regulations are yet to be defined.

Meanwhile, the power sector's commercial and industrial consumer segment is likely to continue driving the storage demand, as done so far. The demand-pull for such battery storage projects will be from solar PV-based distributed generation installations.

With the rise in utility-scale renewable energy capacity, the grid-balancing activities available in ancillary services will become critical. Equally important will be other elements of grid management, such as capacity markets, to ensure network reliability. A timely provision of battery storage might be critical for the network operator to avoid the high opportunity cost of preventing generation or, even worse, deterring prospective investments.

Chile

Chile has been making rapid strides in its decarbonisation goals, having released an enhanced Climate Plan known as a nationally determined contribution (NDC) in April 2020. Energy transition plays a vital role in Chile's climate change mitigation plans, with the country assuming a leadership role in the global renewable energy market. As per BNEF's Climatescope 2021, Chile was ranked the second most attractive market for power investments globally. Coal-based generation capacity is being phased out in a timebound manner to achieve complete withdrawal by 2040. At the end of 2021, ~4.5GW of renewable energy capacity was under construction, slated to be operational by 2023. This corresponds to ~50% of the country's total renewable energy capacity of 8.7GW. Without any pumped storage hydropower, the overarching focus is on expanding battery storage. Access to raw materials like lithium, Chile's second largest reserves globally, presents a strong case for developing the battery ecosystem.

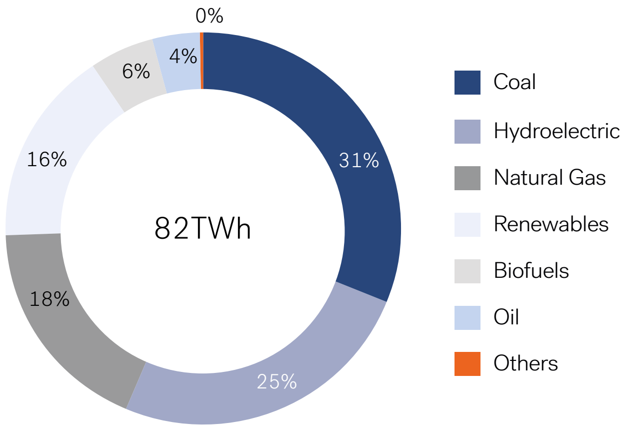
GDP (Current Prices) USD (2021)	316.77bn
GDP Growth Forecast (constant prices) (2022-2026)	1.55%
Currency	Chilean Peso
Country Credit Rating (S&P)	A
Energy Storage Capacity* 2021	180MW
Renewable Energy Share 2021	16%
Energy Storage Outlook 2030	1,792MW

GDP Source: IMF WEO, S&P and IRENA
*Excluding Pumped Hydro

Chile

Energy Mix and Case for Storage

Electricity Generation by Fuel Type (2020)



Source: IEA (2020 Data)

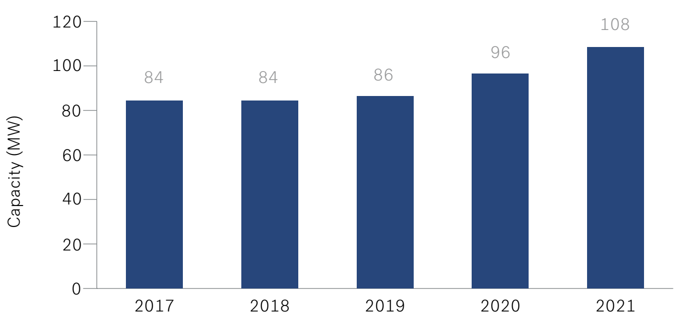
Fossil fuels (coal, oil) accounted for more than one-third of Chile's electricity generated in 2020. Renewable sources, including renewable hydropower, cumulatively accounted for 43.5% of power generation in Chile in 2021, a slight decline over 44.6% in the preceding year. Persistent droughts have curtailed the share of hydropower generation, which is the country's largest source of renewable energy, accounting for ~25% of the power generated in 2020. Of the 14.9GW renewable energy installed capacity in Chile, hydropower accounts for 46%, followed by solar (30%) and wind (21%). Policymakers have set an ambitious target of achieving an 80% share in Chile's energy mix by 2030, almost double that of the prevailing levels. It is estimated that 9.5GW of new flexible capacity will be needed to be added to the grid over the next decade to replace the coal-based generation capacity being retired.

Chile would require an estimated 2GW of storage capacity every ten years to meet its long-term goal of an emission-free electricity grid by 2050. Although Chile's battery energy storage market is still in its infancy, owing to high costs per MW and a low installed base of 64MW, the growth potential is significant. Of Latin America's 129 large-scale energy storage projects, Chile is home to 36. In addition, the Ministry of Energy anticipates a 20% decline in battery costs which would help the commercial aspects of energy storage projects. Consequently, the regulatory framework is being tweaked to accommodate the increased prevalence of energy storage in Chile's power market structure.

Capacity: Status and Trend

Chile's cumulative energy storage capacity stood at about 108MW in 2021. Capacity addition since 2017 has been nominal, with some momentum visible since 2020. The energy storage market has been skewed towards utility-scale storage with no contribution from the residential and commercial & industrial (C&I) segments. Beyond battery energy storage systems ("BESS"), progress is notable in other technologies such as pumped storage hydro (PSH), where Chilean startup Valhalla is developing a 300MW pumped hydro storage project that involves an investment of $600 million. Other innovative concepts are also being explored, such as a proposal to convert mothballed coal-based power plants into large Carnot batteries (molten salt-based storage to power steam turbines). With 65% of the coal-based capacity slated to be retired by 2025, there is considerable scope for this technology if recommendations from a study carried out by Chilean consultancy Inodú in 2018 are validated.

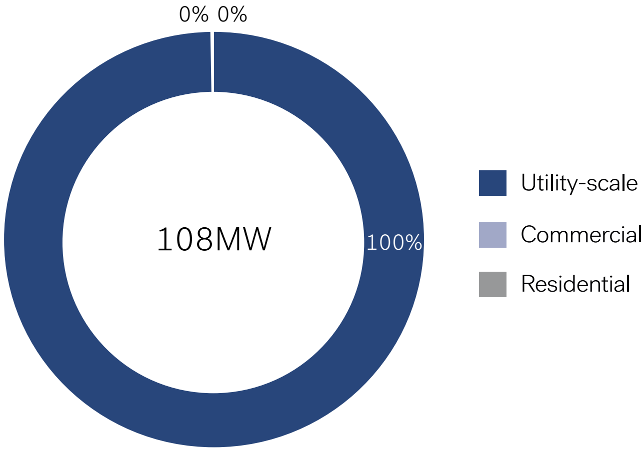
Trend in Aggregate Stationary Storage Capacity



Source: BNEF

Chile

Existing Energy Storage Capacity by Broad Segments



Source: BNEF

Chile's energy storage is fully utility-scale, with most of its capacity used to provide ancillary services. The residential storage segment is unlikely to play a significant role in the future. BNEF anticipates the C&I segment to show some growth, but the market will likely be skewed toward the utility scale. The need for adequate energy storage infrastructure is even starker, considering that 6GW of new renewable energy capacity will likely be added to the 24GW energy grid in the short term. Domestic demand is unlikely to account for all the energy being generated, highlighting the need for a coherent policy on energy storage in Chile which will attract investors. With 25% of the solar capacity in Chile attributable to distributed generation, a national strategy to tap into the same is likely to catalyze energy storage projects, particularly in the C&I segment.

Policy and Regulation

Chile looks set to introduce legislation that will catalyze the energy storage market as policymakers realize the technology's crucial role in balancing the intermittent nature of renewable energy generation and its growing impact on the country's electricity grid. The Chilean Senate passed significant legislation incentivizing the deployment of standalone energy storage in early October 2022. The decree outlines the remuneration mechanism for standalone energy storage in Chile's power market. This was deemed necessary after grid imbalances contributed to 748GWh of renewable energy being dumped in the first nine months of 2022. Chile's electricity grid is characterised by high congestion as an installed capacity of 28GW represents almost three times the domestic demand of more than 11GW. While necessary, extensive improvements to the transmission and distribution network will have to be supported by distributed generation and energy storage capacity to streamline capital expenditures on the electricity grid.

Energy storage has also received regulatory support through power auctions. The last auction was in July 2022. Two developers, Spain-based Fotowatio Renewable Ventures and Canadian Solar-backed Zapaleri SpA were awarded 777 GWh of solar PV co-located with energy storage and wind. This follows an auction in September 2021 when 2GW of renewables and storage capacity was secured and was oversubscribed eight times.

The proposed legislative changes, awaiting a nod from the country's Treasury, address a long-standing demand to introduce additional remuneration mechanisms for injecting energy into the grid. Earlier, storage assets were used only for self-consumption, limiting their use and eroding the commercial viability of standalone projects. This is likely to spur more pure battery storage projects, not associated with the generation, from a mere 64MW or 0.20% of the overall installed capacity of 32.9GW in the country. The latest regulatory change is a series of amendments to support and expand the energy storage market. In 2020, First Solar's 141MW Luz del Norte solar PV plant set a global precedent by offering access to its control systems and inverters to the Chilean grid operator Coordinador Eléctrico Nacional (CEN) for ancillary services (frequency response and load balancing).

Chile

Market Developments and Opportunity

The energy storage market in Chile is witnessing rapid development due to supporting market dynamics. It is estimated that 58MW of battery storage is under construction, while 50MW of liquid air energy storage is in the permitting phase. For energy storage co-located with solar PV plants, 115MW of capacity is under construction, 537MW has environmental clearance, and 1,165MW is in the permitting phase. The wind-battery capacity of 20MW has also received an environmental permit.

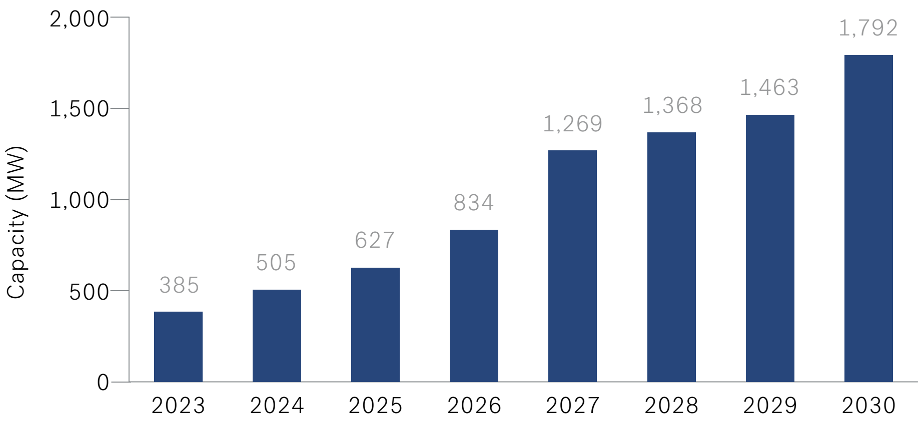
Several high-profile investments in the energy storage space have been announced recently. Foremost among these is the government's $400 million commitment during the COP26 talks in November 2021 to increase the country's energy storage installed base to more than 300MW in partnership with AES Corporation, which is developing a 118MW BESS project in the Antofagasta region. In October 2021, Statkraft was awarded rights to build a 400MW wind power project that could include up to 200MW/1GWh of battery storage. IPP Innergex has plans to invest $128.5 million into two BESS projects with a cumulative installed capacity of 85MW co-located with solar PV plants to provide load-shifting services to the grid, receiving capacity payments and trading energy on the wholesale market.

There are other initiatives underway beyond the utility-scale segment. Stem Inc. has developed Latin America's first virtual power plant, combining solar, wind, and energy storage. The targeted capacity of 1.5GW includes behind-the-meter facilities of between 0.5 and 2MWh. There is notable progress in non-battery storage technologies. The JV between UK-based liquid air energy storage technology provider Highview Power and Chilean backup power generation company Energia Latina SA (Enlasa), which is developing a 50MW/500MWh project involving an investment of $150 million in the Atacama region.

While industry participants have welcomed recent legislative changes tweaking the remuneration mechanism, further deregulation is required to help realize the full potential of energy storage in Chile. A shift away from regulated capacity payments, which cover only part of the total project cost, will be necessary by enabling access to the wholesale power trading market to improve the financial viability of storage projects. Other changes under consideration include setting marginal costs every 15 mins instead of every hour and appropriate price settings for ancillary services.

Outlook

Projected Energy Storage Capacity Addition



Source: BNEF

BNEF expects battery energy storage capacity in Chile to expand rapidly from 2023 onwards and reach a cumulative installed capacity of ~1.8GW by 2030 representing a CAGR of 24.5% during the forecast period. The bulk of the energy storage capacity is expected to be utility-scale, with the residential and, commercial & industrial segments likely to continue playing a marginal role in the overall development of the market. Most of the installed capacity, representing ~95% of aggregate energy storage capacity in Chile, will be deployed for grid services such as energy shifting and ancillary services. Recent steps to impart transparency to ancillary service payment mechanisms are vital in realizing these goals. Further, lithium prices, which have been volatile lately, are expected to moderate, leading to a decline in the cost of batteries and improving the economics of BESS projects.

The underlying dynamics of the power industry in Chile have created a compelling case to accelerate the development of the energy storage market. Persistent droughts have led to a severe shortage in power generated from hydropower resources in recent times, and the situation is unlikely to ease in the short term. In addition, Chile's aggressive decarbonization goals have implied that 65% of the country's coal-based generation capacity will be retired by 2025. The renewables-based generation is being ramped up rapidly, but this has placed the national grid under severe pressure due to poor interconnection and added stress due to increased intermittency in supply. Energy storage is viewed as a long-term and viable option to tackle these issues, and favourable regulatory changes have contributed to attracting the attention of investors.

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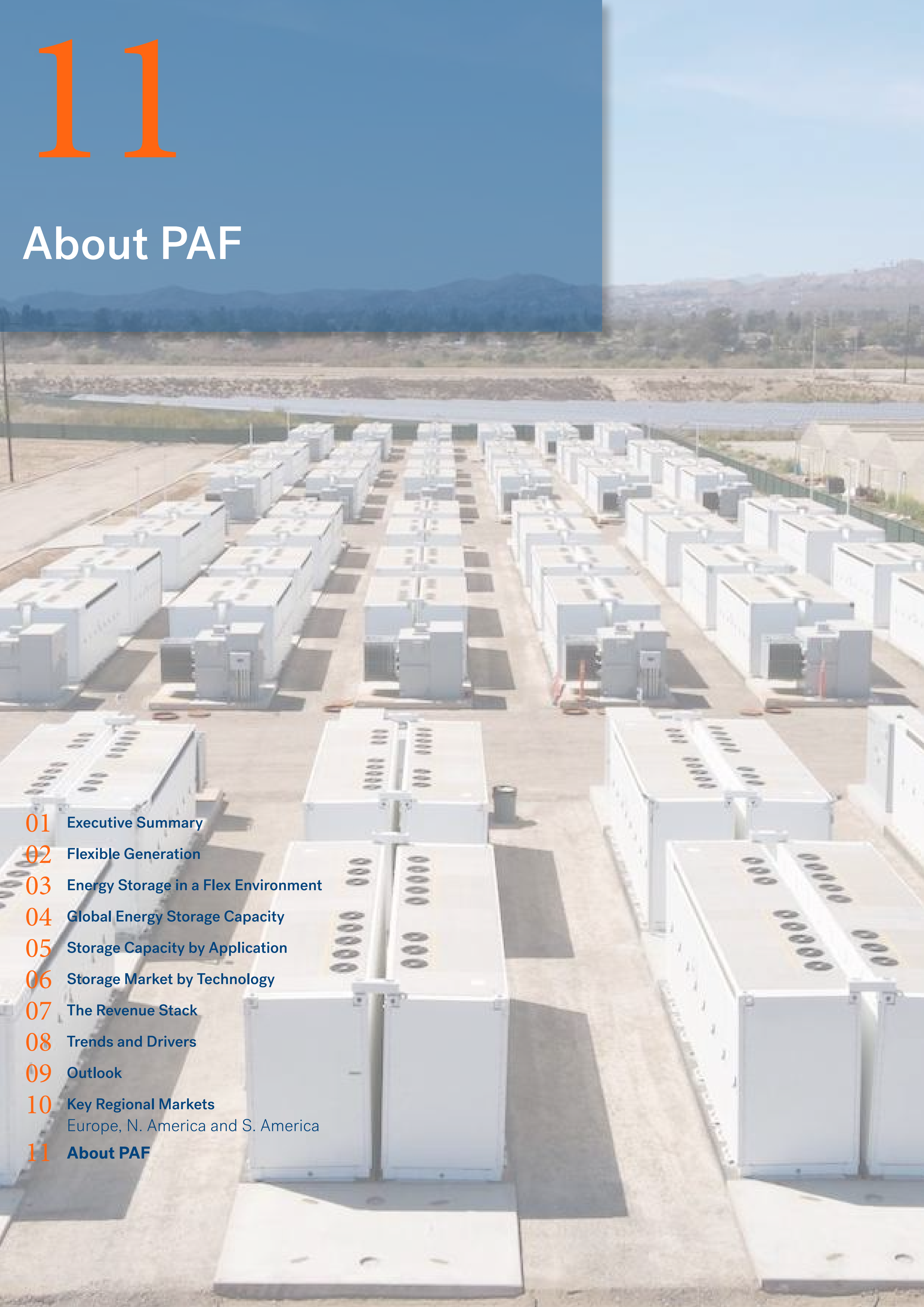
About PAF



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Pan American Finance was founded to advise our clients in achieving their objectives for growth and value creation – through acquisition, investment and capital raising transactions.

Via PAF Securities LLC, we are a member of FINRA/SIPC.

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Team of investment banking professionals with diversified backgrounds and extensive transaction experience in investment banking, capital raising, private equity, and corporate finance & operations.

Complemented by a prestigious group of highly experienced Senior Advisors.

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Directorial and executive leadership positions in the private and public sectors across the America and Europe, including with banks and leading financial institutions.

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M&A and strategic advisory transactions, often private, complex or cross-border, across the Americas and Europe.

Debt and equity capital raising for businesses, projects and highly differentiated fund managers.

Sector expertise in infrastructure, power and renewable energy. **$1.6 billion in M&A advisory across 43 transactions**. **$1.5 billion in project finance & debt advisory across 25 transactions.**

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Our firm has closed **87 transactions** with over **US$5.0 billion** in total transaction value. Our firm has an extensive and successful track record in M&A advisory and capital raising for clean energy and infrastructure.

$1.6 billion

M&A and Strategic Advisory across **43 transactions**

$1.5 billion

Project finance and Debt Advisory across 25 transactions

$1.0 billion

Capital Advisory across 12 **transactions**

$0.8 billion

Capital Placement across **7 transactions**

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Sustainable Energy

Climate Finance

Sustainable Living

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