Electric storage: From idea to action

Electric storage has been around for decades in the form of pumped hydro storage. But recent advances in battery and cutting-edge storage technologies have generated renewed interest in the benefits of storage. **Romkaew Broehm** of RPB Energy Economics, and partners **Daniel Hagan**, **Kirsti Massie** and **Jane Rueger** of global law firm White & Case explain

Policymakers and energy companies are discussing with renewed fervor how to incentivize more storage additions to the grid in US markets and around the world. So far, the benefits of storage remain largely untapped, as most jurisdictions learn to optimize the full potential of its capabilities balanced with policy and regulatory solutions. Growth in storage has been explosive in recent years, but overall market share in all jurisdictions remains extremely small. This discussion primarily focuses on developments and challenges in the US market given its rapid growth. However, lessons learned in the US may be applied to other regional markets across the globe (and vice versa).

The benefits: Why storage?

Electric storage has massive growth potential in global energy markets today principally because of its flexibility, with flexibility being key in today's increasingly renewables-focused energy markets. Electric storage can be used like a generator, injecting electricity onto the grid like traditional generating resources do. It can also be used like a transmitter/distributor, providing applications such as frequency response and load management. It is scalable, leading to grid-scale opportunities as well as behind-the-meter applications.

While pumped hydroelectric storage has historically comprised the vast majority of primary-use case for storage applications, electro-chemical (such as lithium-ion batteries), electro-mechanical (such as flywheels and compressed-air storage), and thermal storage (such as water, ice, molten salts and ceramics) respectively now play roles in power systems with a range of services. Per data from the US Department of Energy in 2017, the following table details the percentages of each technology type for selected use cases, excluding pumped hydroelectric.

US$4.5bn

Projected size of the US energy storage market by 2023

Source: Wood Mackenzie Power & Renewables

Storage technologies in the US in 2017, by percentage

Use case	Electro-chemical	Electro-mechanical	Thermal
Frequency regulation	49.7% (0.95 GW)	2.5% (0.04 GW)	0.0% (0.00 GW)
Electric supply capacity	3.7% (0.07 GW)	12.7% (0.20 GW)	0.0% (0.00 GW)
Black start	2.1% (0.04 GW)	20.4% (0.32 GW)	0.0% (0.00 GW)
Renewable capacity firming	5.2% (0.10 GW)	0.0% (0.00 GW)	72.0% (2.39 GW)
Spinning reserve	9.4% (0.18 GW)	0.1% (0.01 GW)	0.0% (0.00 GW)
Onsite power	0.0% (0.00 GW)	54.8% (0.86 GW)	0.0% (0.00 GW)
Electric energy time shift	7.9% (0.15 GW)	7.0% (0.11 GW)	4.2% (0.14 GW)
Renewable energy time shift	2.6% (0.05 GW)	0.0% (0.00 GW)	14.5% (0.48 GW)
Total (including other uses)	1.91 GW	1.57 GW	3.32 GW

The adoption of storage can help lower energy costs. The nearly universal decline in costs throughout the supply chain of both renewable energy technology and batteries for storage can introduce more competition into the electric markets. Such a shift potentially saves ratepayers money by displacing more expensive or less energy-dense generation (such as coal, or even nuclear in jurisdictions without emissions credits). It also enables the "traditional" generation that remains to function more efficiently, avoiding numerous stops and starts. As energy storage penetrates the US market, some benefits to investment

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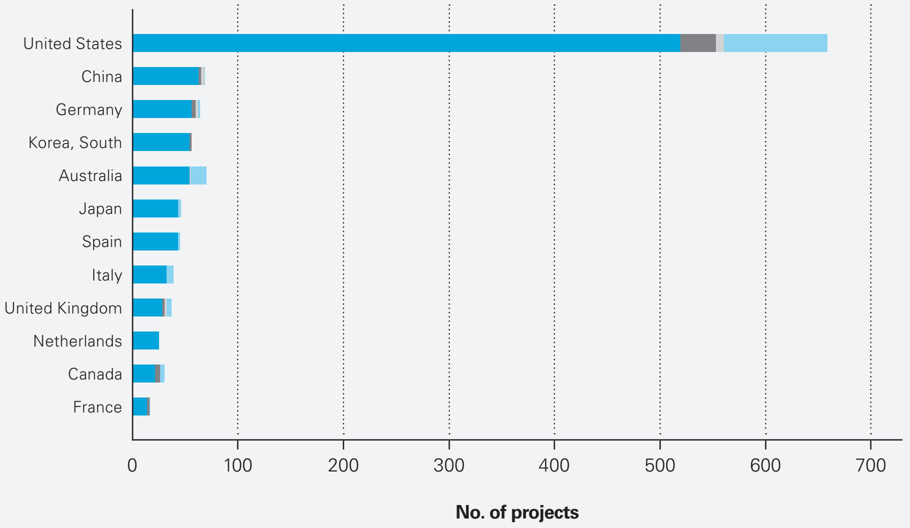
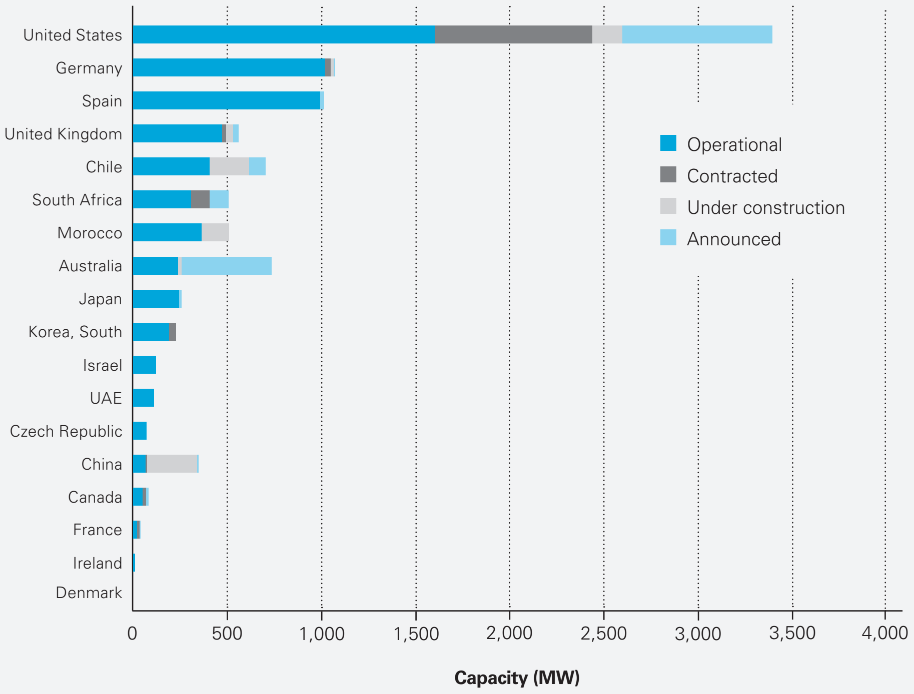
Numbers of electric storage projects



The United States is a leading country in the non-hydroelectric storage investment. Most of the electric storage growth occurred in the organized RTOs/ISOs markets, particularly in California where the state government and regulators have been promoting renewables and decarbonization policies. This is also true in Germany and Spain, although the numbers and capacity of their announced electric storage projects are much lower than those in Australia, which is double the existing number of operational projects. The majority size of these projects is below 10 MWs of capacity. For a few large-sized projects, their capacity range is from 100 MWs to 400 MWs. The technology of these large-scaled projects varies. Almost all of them reported their main functions are to support renewables time-shifting or capacity-firming.

Source: The data for Figure 1 and Figure 2 were obtained from the DOE Global Energy Storage Database, The National Technology & Engineering Sciences of Sandia, LLC. They can be accessed at https://www.energystorageexchange.org/projects

Total installed capacity of electric storage projects by country



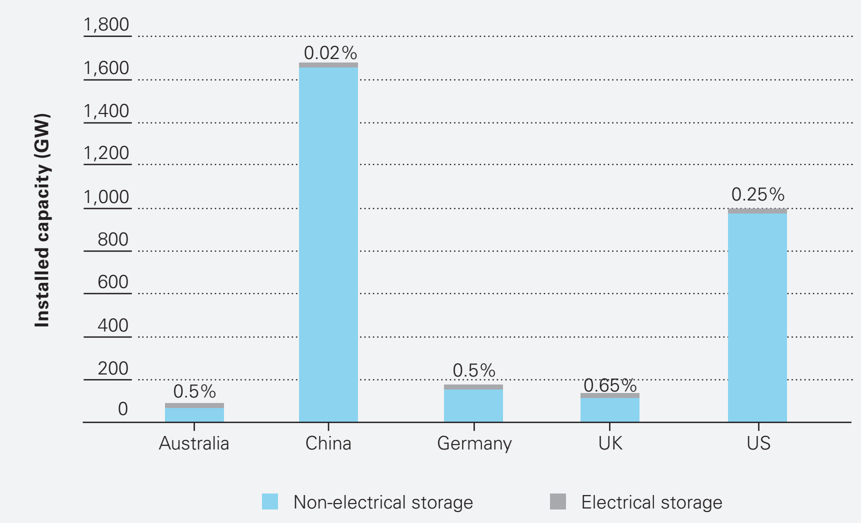
Source: The data for Figure 1 and Figure 2 were obtained from the DOE Global Energy Storage Database, The National Technology & Engineering Sciences of Sandia, LLC. They can be accessed at https://www.energystorageexchange.org/projects

may also be the avoidance of indirect/remote costs down the line. For instance, if paired with a renewable generator, a storage project will have contributed to reduced greenhouse gas emissions (i.e., compliance costs, environmental regulations in the future, potential carbon taxes/costs of carbon).

Investing in energy storage may also help relieve stress on existing transmission and distribution infrastructure by resolving bottlenecks on the grid—deferring the need for capital-intensive upgrades to aging infrastructure. Innovation in the storage segment should alleviate stress on aging transmission and distribution infrastructure by reducing use of that infrastructure to transmit generation to resolve local frequency or loading issues. Instead, local storage-based solutions can serve this frequency response function.

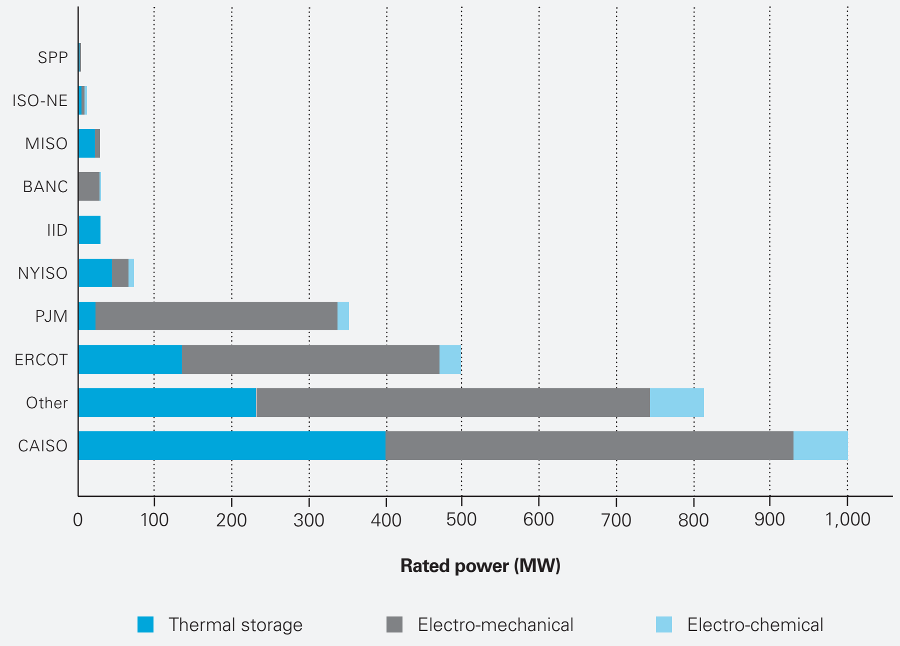
The proliferation and deployment of battery storage technologies can accelerate a shift towards renewable energy sources. As some jurisdictions set more aggressive targets approaching or at 100 percent renewable power procurement,

Electric storage as percentage of total installed capacity for selected countries



Source: The percentages represent shares of electric storage installed capacity relative to total installed in each country. The capacity year of each reported varies between 2017 and 2018 based on data sources. The reported years of Australia, China and the UK are based on 2017, while those of the US and Germany are based on 2018.

Non-hydroelectric storage in the US



Source: The data for Figure 1 and Figure 2 were obtained from the DOE Global Energy Storage Database, The National Technology & Engineering Sciences of Sandia, LLC. They can be accessed at https://www.energystorageexchange.org/projects.

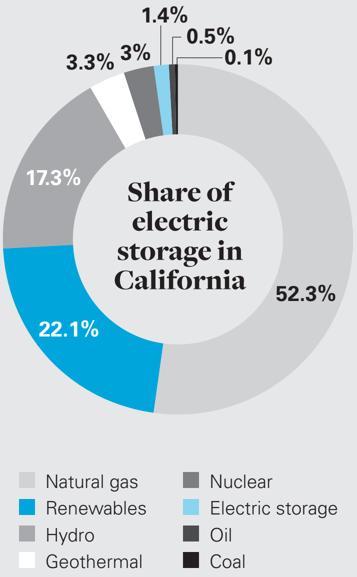
> “The strength of storage—its flexibility to serve generation, transmission and/or distribution needs—also makes it hard to fit within existing regulatory frameworks.

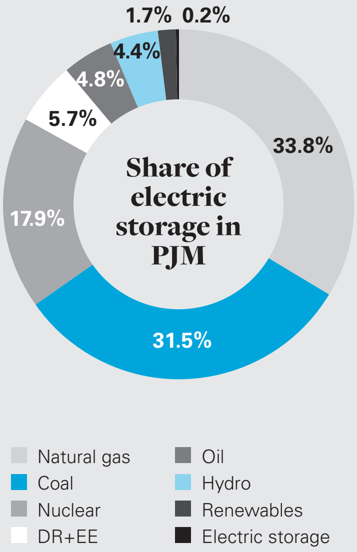
grid stability and flexibility have become increasingly relevant issues. The grid needs resources that can provide fast ramping, frequency response and load management. Grid-scale batteries are capable of serving as peaking resources that will ultimately help to smooth out fluctuations in power markets with large proportions of solar generation or other intermittent renewable resources. As the product matures, and prices for storage solutions fall, more markets will be able to link renewable production to storage. This trend will lead to more balanced and reliable power markets while enhancing the viability of integrating intermittent resources as frequently as needed. The broad application of electric storage—particularly large, utility-scale projects—will only complement current power markets while sending strong market signals that more renewable resources can be developed for the practical needs of the ever-expanding grid.

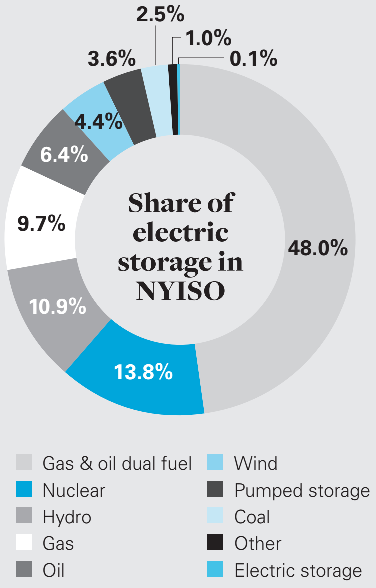
The challenge: Finding the right signals to spur large-scale investment

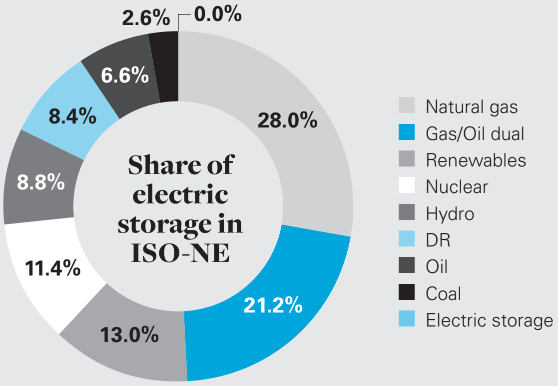
Policymakers, engineers and grid operators tend to agree on the

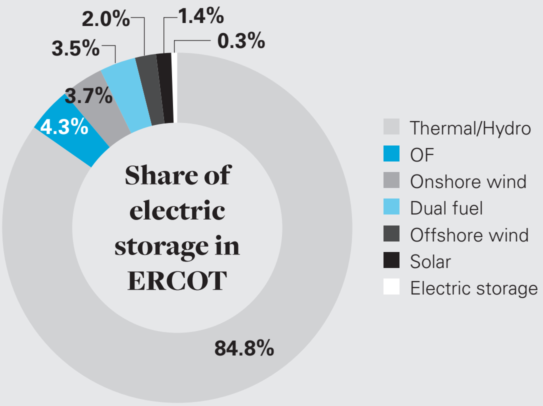
De minimis shares of existing, under contract and under construction of electric storage projects in US RTOs/ISOs







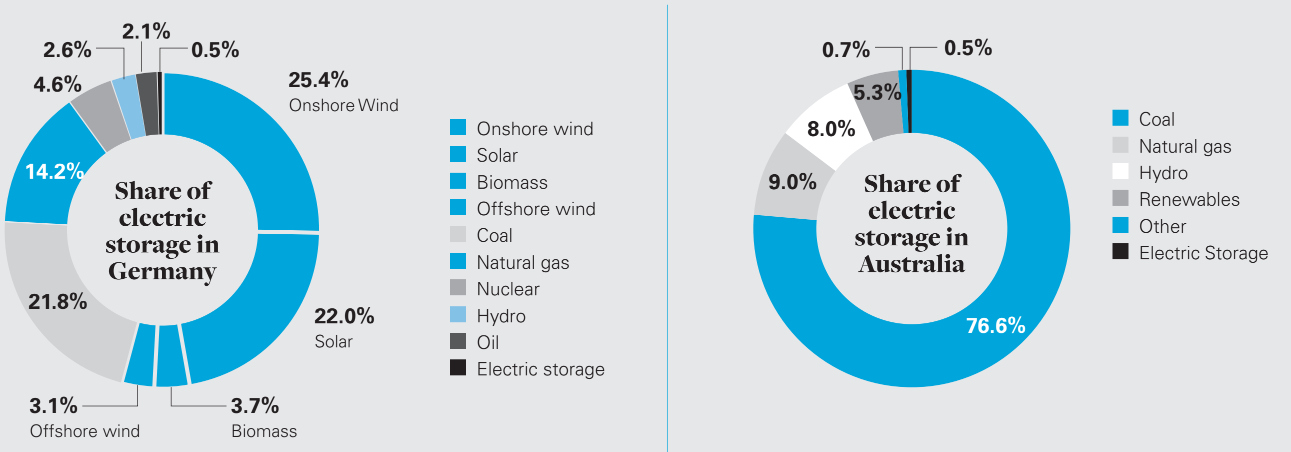




Sources and notes:

- For California, the 2017 installed in-state generation capacity data were obtained from the California Energy Commission at https://www.energy.ca.gov/almanac/electricity_data/electric_generation_capacity.html
- For PJM, the 2017 installed in-state generation capacity data were obtained from PJM at https://pjm.com/-/media/markets-ops/ops-analysis/capacity-by-fuel-type-2017.ashx?la=en
- For NYISO, the 2018 installed generation capacity data were obtained from Table II-1a of NYISO's 2018 Load & Capacity Data
- For ISO-NE, the 2018 installed generation capacity data were obtained from ISO-NE's CELT Report, May 2018. The renewables capacity also includes behind-the-matter photovoltaics
- For ERCOT, the installed generation capacity data were obtained from ERCOT's 2019 Report on the Capacity, Demand, and Reserves in the ERCOT Region. The QF refers to "Capacity from Private Use Networks." The electric storage capacity data were from NTESS. Only operational, contracted and under construction projects were included

De minimis capacity shares of existing, under contract and under construction of electric storage projects to total installed capacity in Germany and Australia



Sources and Notes:
For Germany, the installed generation capacity data were obtained from AGEE, BMWI, Bundesnetzagentur, which were obtained from https://www.energy-charts.de/power_inst.htm?year=2018&period=annual&type=power_inst. The electric storage capacity data were from NTESS. Only operational, contracted and under construction projects were included.

For Australia, the installed generation capacity data were obtained from Australia Energy Market Operator by multiplying shares of annual generation by fuel type to 2017 installed capacity. The data can be accessed at: https://www.aemo.com.au/-/media/Files/Electricity/NEM/National-Electricity-Market-Fact-Sheet.pdf. The electric storage capacity data were from NTESS. Only operational, contracted and under construction projects were included.

benefits of storage. So why such relatively small levels of market penetration to date?

Storage operating characteristics make it hard to fit within established regulatory frameworks and market assumptions

The strength of storage—its flexibility to serve generation, transmission and/or distribution needs—also makes it hard to fit within existing regulatory frameworks. For example, in the US—as in the UK and Europe—investors in transmission and distribution assets are with limited exceptions compensated through a regulated rate that reflects the cost to provide the service (plus a set rate of return on investment). Conversely, there are robust energy and capacity markets that allow for negotiated rates for generation services that reflect the value of the services to buyers. While FERC has thus far allowed storage assets to choose whether to be compensated as transmission/distribution under a cost-based model or as generation under a market-based model, it has not gotten comfortable with a mechanism for storage to toggle between cost-based transmission/distribution services and market-based generation services over time. This issue is not unique to the US markets; for example, in the UK, classification of storage as generation requires a generation license, and limits the ability of the technology to switch between generation services and transmission/distribution services.

3.9 GW
Projected energy storage capacity in the US by 2023

Source: Wood Mackenzie Power & Renewables

Moreover, the unique operating characteristics of electric storage as compared to generation transmission and distributions can make it difficult to compensate storage appropriately. Product definitions and participation models for generation tend to restrict the ability of storage assets to participate because of storage operating characteristics. For example, capacity markets—the primary source of revenue streams for new generating units—are presently not congruent with storage under all scenarios. A capacity provider must be able to discharge power to the grid immediately upon dispatch by the system operator, particularly during disruptions or fluctuations. It also must be able to discharge continuously for as long as needed by the system operator. In return, capacity providers are paid stable capacity revenues that allow financing of even peaker units that don't run often and lack regular energy revenues. While commercial batteries deployed in storage projects are becoming larger and harnessing more power, most are limited to approximately four to six hours worth of discharge capability, and cannot discharge on demand once depleted without time to recharge. If the capacity market still requires a provider to supply its resource beyond that timeframe, the technological limitations of storage could result in major penalties to storage providers and potential ramifications to the overall stability of the grid. Reforms to capacity market rules could bridge the gap between this (at present) weakness of storage resources.

The applications of electric storage in US power markets are numerous and span the value chain

Illustrative electric storage values from multiple-use applications

- Customer
- Distribution
- Transmission
- Environment
- Flexibility
- Capacity
- Ancillary services
- Energy

Sources: Broehm (2017)

for regional grid operators, utilities and end-use customers. However, some applications cannot be stacked down the value chain, requiring a careful assessment of how to most appropriately deploy storage for certain goals. The benefits of storage can be leveraged by customers, utilities (and corresponding utility infrastructure) and wholesale markets. For instance, the value chain for increased reliability may favor customers and markets in terms of product (less frequent outages, faster response and so on), while the utilities would leverage that benefit as a means to defer investment in new transmission or distribution infrastructure.

On top of that, electric storage encompasses multiple technologies with very different performance profiles. Different technologies are also at various stages of development, cost competitiveness and market experience. It is difficult to develop a "one size fits all" regulatory framework that levels the playing field for such a wide array of technology.

Co-optimization of revenues; market rules

From an economic efficiency framework, resources should be compensated based on their incremental value. As discussed above, the value of electric storage resources arises from their operational flexibility to quickly respond to a system's generation and consumption needs in multiple-use applications—generation, transmission, distribution and customer services. Broadly speaking, each of these values can be quantified and added up to derive the total expected revenue of electric storage. Each value stream is derived based on a system's avoided cost that a particular electric storage resource provides to the system. Nevertheless, the values from generation applications, namely capacity, energy and ancillary services, should not be quantified in isolation.

> **"The generation values of an electric storage resource could be captured from wholesale power markets, as the resources can provide capacity, energy, and ancillary services simultaneously.**

The generation values of an electric storage resource could be captured from wholesale power markets, as the resources can provide capacity, energy and ancillary services simultaneously. Electric storage resources that can discharge and charge instantaneously without having to worry about ramping rate, startup time and minimum load requirements, would be able to capture revenue in the regulation up, regulation down, spinning reserves and flexibility (ramping) markets, in addition to the energy, resource adequacy (a.k.a. capacity) markets. However, their values can vary, depending upon their flexible operating ranges and the performance of their storage technologies. Some types of battery technologies may have low power to follow frequency control signals continuously, but have longer duration for storing energy. Some offer a few seconds of response time under automatic generation control (AGC) signaling, but they may have limited duration for dispatch. The latter could sell into the regulation, spinning reserves, energy and capacity markets, while others could sell only into the capacity and energy markets.

These services are interdependent, as market and system operations are governed by national or regional reliability standards and government's regulations. In the US independent system operator (ISO) markets, the operating reserves and energy procurement allocation and pricing are a result of co-optimization of energy and ancillary services products. Generating resources that want to sell into a regulation up/down market, for instance, are committed to provide both short-term primary reserves and energy, like a call/put option contract. Under this option contract, a qualified generating resource would earn an hourly regulation price from a day-ahead regulation market plus a real-time energy payment (a strike price) when it is called by its ISO. If it is not called for energy, the resource will not earn the energy payment. Prices of ancillary services therefore are based on the forgone values of providing energy. Electric storage resources are also subject to this co-optimization market rule even though they are capable of faster startup times and higher ramp rates than traditional generating resources. Similarly, if the capacity of electric storage resources has been awarded in a capacity market, these electric storage resources are obligated to have their committed capacity available for use by the system dispatcher. Moreover, organized power markets consist of the day-ahead and real-time markets that present separate but interrelated revenue streams for market participants.

Thus, for an electric storage resource to capture the potential maximum values from the wholesale generation

US$400

Current cost of a lithium-ion battery installation per kilowatt-hour

Source: Moody's

markets, one would need to co-optimize the electric storage resource across multiple value streams. One does not only need to know when to discharge (selling energy) and charge (buying or storing energy) across hours of a day or a week, but also has to know how to allocate the electric storage resource's capacity and energy across capacity, energy and/or ancillary services products as well as how to develop operating strategies to arbitrage opportunities between day-ahead and real-time markets. Figure 2 displays an illustrative example of how a battery storage asset can offer energy and ancillary services into ISO energy and regulation up and regulation down markets, respectively. The top panel presents an electric storage resource offering in regulation up and regulation down markets, while the second panel shows its sales in day-ahead and real-time energy markets. The last panel displays an electric storage resource's state of charge (SOC), which is one of the parameters that needs to be accounted for when deciding whether to award an electric storage resource for providing ancillary services.

A co-optimization model involves maximizing potential revenue of an electric storage resource by allowing the storage resource to serve in different product markets, depending upon which market is the most valuable at the time. The model takes into account the electric storage resource's special characteristics (such as its SOC, upper and lower charge limit, maximum and minimum energy discharge and charge rates, and efficiency rate) and forecasted wholesale market prices of energy and ancillary services. These prices can be derived from forward curves and other relevant data including volatilities and elasticities of these products. The ability to forecast prices is therefore important, as uncertainty could significantly increase or decrease the expected revenue stream.

According to the Data Global Energy Storage Database, most of the non-hydroelectric storage capacity in the U.S. provide Regulation or

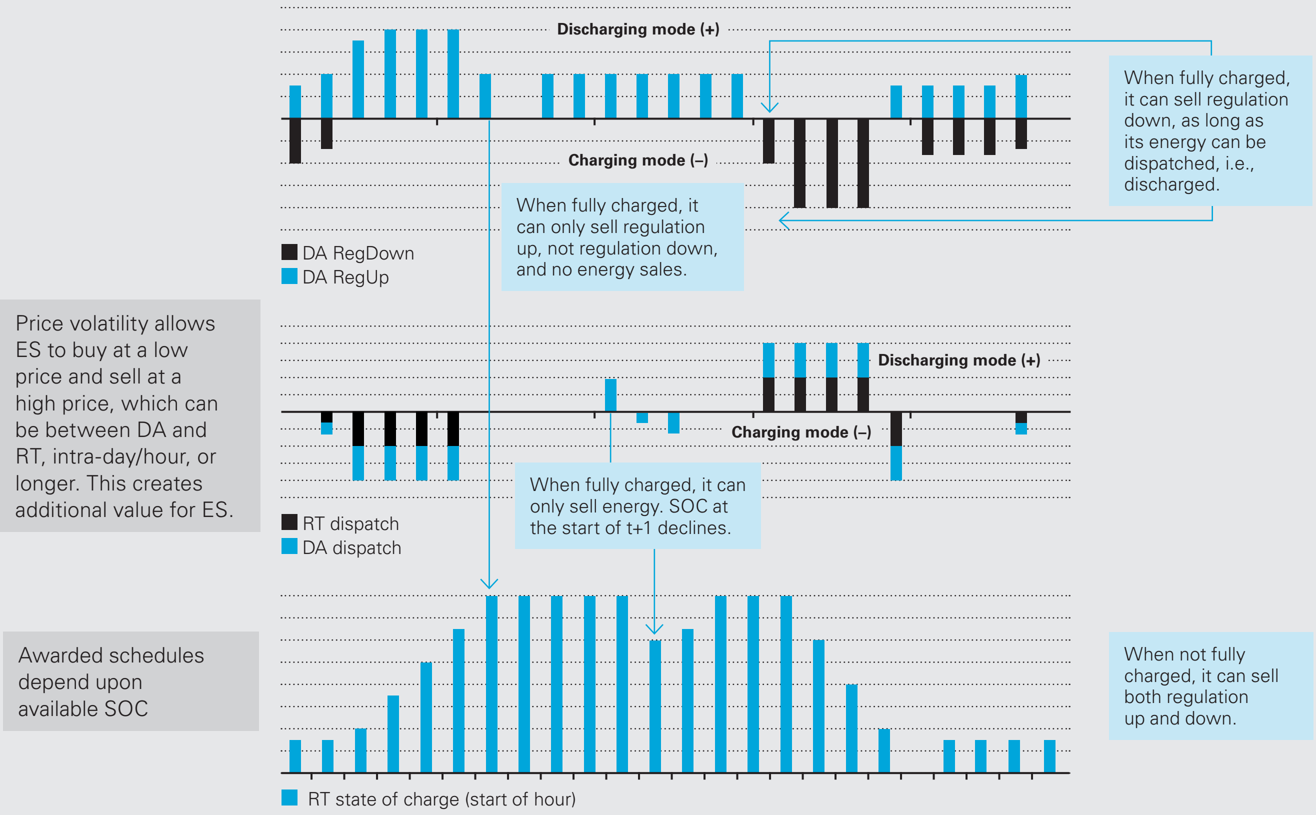
46%

Batteries' share of global end-use market for lithium

Source:
US Geological Survey data

> **Contracted revenue streams are critically important to attracting investors and lenders to energy storage projects.**

An illustrative example of battery storage dispatch



When fully charged, it can sell regulation down, as long as its energy can be dispatched, i.e., discharged.

When fully charged, it can only sell regulation up, not regulation down, and no energy sales.

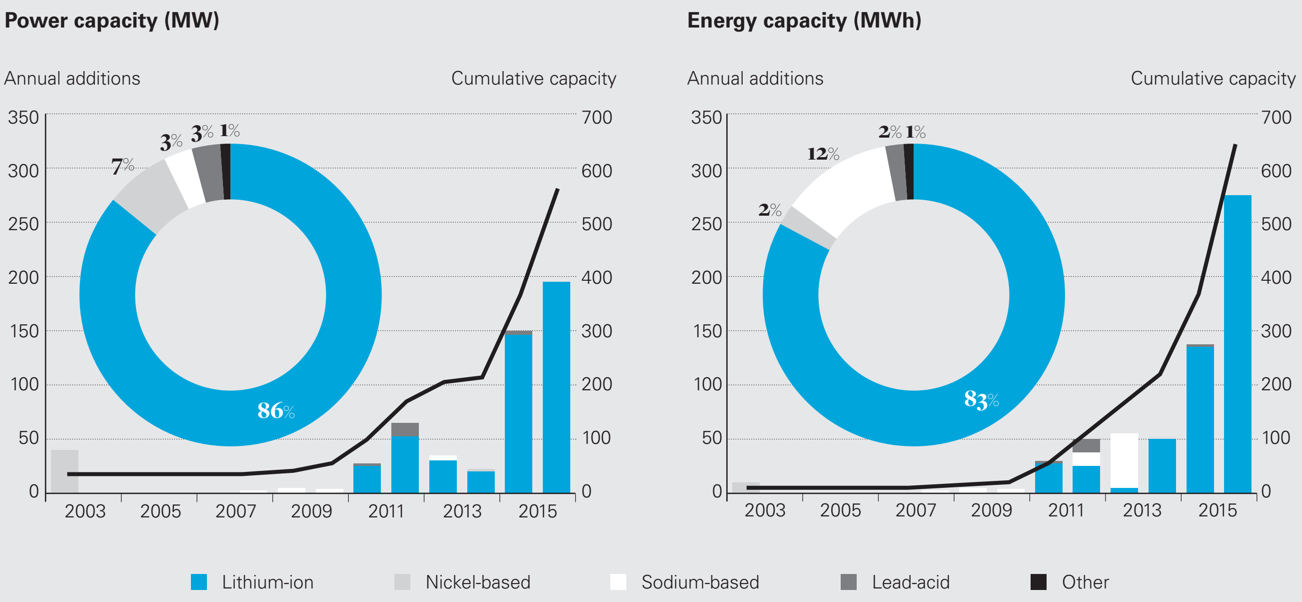
Price volatility allows ES to buy at a low price and sell at a high price, which can be between DA and RT, intra-day/hour, or longer. This creates additional value for ES.

When fully charged, it can only sell energy. SOC at the start of t+1 declines.

Awarded schedules depend upon available SOC

When not fully charged, it can sell both regulation up and down.

US large-scale battery storage capacity by chemistry (2003–2016)



Sources: US Energy Information Administration, Form EIA-860, *Annual Electric Generator Report*

frequency responses services, which are procured by an ISO. Hence, the depth of the ancillary services markets is limited. The demand for this product is relatively small when compared to the demand for day-ahead or real-time energy. Pacific Gas and Electric's (PG&E's) Electric Program Investment Charge (EPIC) project, for instance, successfully earned energy and ancillary services payments from the California ISO markets when it offered two electric storage demonstration projects into these markets in 2014 and 2016. Their revenues from the regulation up and regulation down markets were significantly higher than the revenues in the day-ahead, real-time energy and spinning reserves markets. The EPIC project may foretell more opportunities for storage resources to provide ancillary services as compared to historical trends, largely prior to market reforms recognizing the other characteristics of storage.

Through its EPIC project, PG&E identified several challenges, including how the California ISO incorrectly managed their storage resources' SOCs, which in turn had an adverse impact on its market revenue from these projects. Electric storage resources in other US ISO markets also experienced this similar issue, if not worse. Market rules typically did not recognize special features of the electric storage resources. To participate in wholesale power markets, electric storage resources must register under frameworks designed for other types of resources such as demand-response resources, generation resources or use-limited resources. These participation models did not accommodate or properly compensate the unique features of electric storage technologies. For example, the Midcontinent ISO's market rules for Special Energy Resources (SER) required SER resources that participated in the regulation market to provide energy for an hour and then be forced to be unavailable for the next hour. These resources were not allowed to self-manage their own SOC, reducing optimal performances, undervaluing these resources and, in turn, reducing the resources' life expectancy. In FERC Docket No. EL17-8 (2017), Indianapolis Power & Light asserted that the Midcontinent ISO's SER procedure of over-dispatching could significantly decrease battery cell life from ten years to three years. In some ISOs, electric storage resources can only participate in a forward capacity market if they can provide continuous energy for a long duration, which many cannot do. We explain below how FERC is trying to unlock these barriers by requiring ISOs to create market rules recognizing special characteristics of electric storage resources.

98.8%

Lithium-ion battery market share in 4Q 2017 in the US

Insufficient contracted revenue streams

Contracted revenue streams are critically important to attracting investors and lenders. While storage can qualify for many different revenue streams, in many jurisdictions these are not contracted or forward revenue streams (such as bilateral agreements or forward capacity value). While FERC has taken steps to remove barriers by requiring RTOs/ISOs to create storage participation models, the revenue streams from the market may be volatile, and availability of capacity revenues (which are less so) depend on fulfilling certain reliability requirements.

Many studies have suggested that the revenue from energy and ancillary services markets is not sufficient for an electric storage resource to recover its full fixed cost. Moreover, the amount of revenue is uncertain due to market price volatility. Thus, a significant share of the electric storage resource's revenue would need to come from a capacity market (either organized or bilateral capacity market).

To receive a capacity payment, an electric storage resource must act as a peaker to lower the risk of unserved energy events or loss of load probability. Market rules, however, usually require an awarded capacity resource to provide firm energy for a continuous duration. The capacity payment would depend upon the electric storage resource's ability to meet this peak-shaving requirement. Under the current rules in California and New York, for example, to be eligible for a capacity credit, an electric storage resource must be capable of providing energy for at least four consecutive hours. If the resource could not perform when it is called by an ISO, a performance penalty is applied.

However, as the penetration level of intermittent resources increases, a system may require an awarded capacity resource to provide its firm output for a longer duration (e.g., from four to six hours). For an electric storage resource with only four hours of stored energy, this implies that its capacity value could decline.

Scale of investment

Most electric storage installations today are small in size. Institutional investors and private equity tend to be interested in assets that support large capital investments worth the cost of due diligence and other investment costs. Currently, this means investments are being made in portfolios of storage assets, but this limits the electric storage market to large developers with a national or global reach. In addition, portfolio aggregation can increase risk of the overall investment, for example proliferating siting or permitting risks across multiple sites in multiple jurisdictions.

Sourcing and risks of storage supply chain

In the US and globally, lithium-ion batteries are far and away the predominant technology, accounting for 98.8 percent of market share in 4Q 2017. Lithium-ion batteries have led the market in each quarter for the past four years. Lead-acid battery installations comprised a bulk of the market in 2012; however, since that period, lead-acid (along with sodium-based batteries and flow batteries) have been substantially outpaced by lithium-ion. Flow batteries are an emergent technology and may eventually achieve higher market share. There also remains significant global R&D efforts advancing other, more novel, technologies. Each has different pros and cons, and different operating characteristics in key areas such as cycle times and duration and speed of discharge.

Over the past several years, the cost of lithium-ion batteries—also the most common in energy storage applications globally—has decreased, priming battery storage for greater investment. Most industry analysts expect this trend to continue. According to Moody's research, the current cost of a lithium-ion battery installation is approximately US$400 per kilowatt-hour (of which US$200 is the battery itself and US$200 for the remaining electrical components). Perhaps most importantly to energy markets and luring further investment, the energy density of lithium-ion batteries has increased concurrently with the decline in cost. Simply put, as the technology has improved and matured, batteries have cost less while increasing in capacity. By leveraging economies of scale and continuing to forge ahead, future technology gains are likely to spur interest in financing projects considered more economically viable (and stable) than in the past.

338 MWs

Energy storage installations in the US in 2018

Source: Wood Mackenzie Power & Renewables

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> **Over the past several years, the cost of lithium-ion batteries has decreased, priming battery storage for greater investment.**

Political instability and pressures on securing these materials may lead to supply chain disruptions, however, particularly as battery production increases. According to *US Geological Survey* data, batteries comprise 46 percent of global end-use markets for lithium. Technology companies in the US and Asia, seeking to maintain and expand on a pipeline of lithium, have prioritized development of new mining operations in order to support the demand stemming from vehicle manufacturers and battery suppliers.

Cobalt is more susceptible to supply disruptions from unrest and political conflict; the Democratic Republic of the Congo is the main provider of the metal (in addition to copper), a nation with a longstanding track record of volatility. From 2016 to 2017, global cobalt prices doubled, slowing growth for battery manufacturing. A study conducted in 2018 by the Helmholtz Institute Ulm of the Karlsrule Institute of Technology identifies areas where shortages may occur in the future. As a result, the authors recommend that research and development efforts home in on "post-lithium" battery designs that avoid extracting cobalt from politically delicate areas of the world. Approaching these tenuous yet crucial markets with geopolitical stability and environmental sustainability in mind may allay some risk factors—for purchasers and suppliers alike—and further, developing alternatives that diminish the comparative advantage of nations such as the Democratic Republic of the Congo, in effect exerting soft power on oppressive regimes. If such a nation can no longer

Topic	US	UK	Australia	Germany	China	India
Eligibility to provide all services	🟦	■	🟦	▨	▨	▨
Ability to de-rate capacity	🟦	🟦	🟦	🟦	🟦	🟦
Participate as wholesale seller & buyer	🟦	🟦	🟦	▨	🟦	🟦
Bidding parameters	🟦	■	🟦	■	■	🟦
State of charge management	🟦	▨	🟦	▨	▨	🟦
Minimum size	🟦	🟦	▨	🟦	🟦	🟦
Price for charging energy is LMP	🟦	🟦	🟦	🟦	▨	🟦
Metering & accounting	🟦	🟦	🟦	🟦	▨	🟦

🟦 Compliance ▨ Uncertain compliance ■ Noncompliance

monopolize the global supply of cobalt, their incentive to engage in stable behavior may be strengthened in order to maintain a large market share and secure revenues for the government. By 2050, demand for cobalt may double the reserves currently exploited across the globe. Lithium-ion batteries are essential for at least the first stage of wide deployment of electric storage, and ensuring the supply chain of metals for the intermediate future must remain a priority to companies and state actors seeking to speed along the technology. As illustrated in the *Mining & Metals* 2019 report and survey produced by White & Case, investors perceive the lithium market as likely to rebound and are bullish on the prospects for copper in the near future, continuing that trend. Cobalt, on the other hand, faces a more tumultuous outlook due to the attendant political risk. Overall, the White & Case report characterized the battery sector as the "good news" story in mining and metals over the past several years, with strong expectations that investment will sustain that run.

Investment in recycling and reuse is lagging

Another challenge that the anticipated exponential increase in battery storage poses is what to do with batteries after they reach the end of their useful life on the grid. The Global Battery Alliance project of the World Economic Forum notes that 11 million tons of spent lithium-ion batteries are forecast to be discarded by 2030. Improper handling of disposal of spent batteries can pose a significant threat to human health and the environment. Yet, in many jurisdictions—including the US—little coordinated effort has been made thus far to spur development of battery recycling or reuse programs. The European Union has recognized the potential issue arising from the increased use of batteries and accumulators, and the need to ensure appropriate recycling and disposal thereof. The Batteries Directive 2006/66/EC introduces measures to maximize the separate collection and recycling of waste batteries and accumulators by introducing specific recycling targets according to the types of batteries e.g., lead-acid, nickel-cadmium and industrial/automotive batteries, and rules for the monitoring of compliance by Member States. Many Member States have introduced their own legislation to implement the provisions of the Batteries Directive, thereby implementing the provisions of the directive into domestic law." More research and investment in technologies that can safely and efficiently refurbish used batteries for a second life in another application is necessary as more battery storage is added to the grid.

> "Energy storage projects can potentially offer additional services and collect additional revenues.

Possible solutions: What are the right signals?

According to projections by Wood Mackenzie Power & Renewables, the energy storage market in the US will reach US$4.5 billion in 2023, following rapid growth in 2019 and 2020 in particular. In terms of capacity, these projections indicate there will be 3.9 gigawatts of storage deployed in the US in 2023—a significant leap forward relative to the 338 MWs installed in the US in 2018. But for storage to truly reach its potential, solutions to the problems above must be found.

Answers may be different for each jurisdiction

Whether a significant market share of electric storage develops in a particular jurisdiction depends on many factors, such as the design and operating characteristics of the jurisdiction's transmission/distribution grid, prospects for significant renewable build-out and the kinds of incentives offered by the jurisdiction for investment in storage. For example, without the growth of solar and wind, there is substantially less incentive to attach storage, and countries without a robust renewable sector may find progress slow on storage. However, a jurisdiction's commitment to renewable growth does not necessarily equate to storage growth; in the past year, a Minnesota study concluded that it would be more efficient to overbuild renewable resources in the state (with attendant curtailments) than to build sufficient storage to avoid curtailments altogether.

Jurisdictions across the globe with burgeoning storage sectors also vary widely in mechanisms to incorporate the resource. As is common with transmission projects and rate proposals, most utility-scale electric storage installations are subject to approval by a state public utility commission (or other agency with a similar remit). There is room to engineer creative—and potentially more efficient—solutions for bringing storage projects online. Public utility commissions are conducting assessments and soliciting stakeholder feedback regarding potential multi-use applications of electric storage. These agencies are contemplating how to modify existing tariffs or market rules in order to incorporate storage without contravening contractual arrangements or provisions. As it stands, state utility regulators in California, Hawaii, Massachusetts, Minnesota, New York and Texas are undertaking such efforts relating to multi-use applications.

The incentive to leverage the benefits of multi-use applications will necessitate changes to the financing of such storage projects in addition to the regulatory hurdles alluded to prior. Financing structures and models may incorporate stacking the multi-use applications of storage systems. By doing so, lenders and borrowers would develop contracts and compliance protocols to operate these systems—and tap into the variety of products and services via multi-use applications—across different regulatory programs and jurisdictions for a range of customers.

Regulators can mandate changes to market structures to smooth access for storage

Regulatory barriers in the US are being eliminated at both the federal and state levels.

In February 2018, FERC issued Order No. 841, landmark guidance requiring regional grid operators to accommodate electric storage in their capacity, energy and ancillary services markets. With this order, FERC aims to remove barriers to the participation of electric storage resources in the US's organized wholesale electric markets and encourage use of the full range of electric storage capabilities. It is generally thought that the order will be effective and will increase storage deployment; according to one estimate, the order will facilitate the installation of up to 50 gigawatts of new storage. In context, that would represent the equivalent of 86 percent of all installed solar capacity to date. The proportion of electric storage in the US market spurred by Order No. 841 and similar policy reforms seems to have the potential to be substantial in the short- and medium-term. Further, FERC's recognition that organized market rules should encourage the design of storage resources that provide competitive capacity, energy, and ancillary services speaks to the significance of storage in the future electric grid.

15

Utilities in at least 15 states have included energy storage in their integrated resource plans (IRPs)

At a high level, FERC Order No. 841 directed the regional grid operators to remove barriers to the participation of electric storage by December 2019 through storage participation models that achieve the following objectives:

- Create a minimum size requirement for electric storage resources in order to participate in the wholesale markets
  - Not to exceed 100 kilowatts
- Broaden the services electric storage resources can provide based on products that are technologically feasible
  - For example, products provided through capacity, energy and ancillary services markets, and services not procured through organized markets such as black start service

State	State-level or utility-level financial incentive program for energy storage projects	Procurement mandate or goal for energy storage projects
Arizona	■	🟦
California	■	■
Maryland	■	
Massachusetts	■	■
Nevada	■	▨
New Jersey		■
New York	■	■
Oregon		■

■ Program implemented 🟦 Proposed by Arizona Corporation Commissioner ▨ Pending implementation

- Allow electric storage resources to be dispatched in the wholesale markets
  - Set market-clearing prices as both wholesale buyer and seller
- Clarify and account for the technological and operational characteristics of electric storage
  - Devise new bidding parameters and other market design modifications

The proposals submitted by regional grid operators offer unique approaches suited to their markets and current degree of storage integration. For instance, the proposal of the California system operator, CAISO, includes only minor changes because its market rules were already in compliance with most of Order No. 841's requirements. In fact, CAISO may serve as a useful policy and regulatory model for other grid operators to emulate, as the order routinely pointed to CAISO's treatment of electric storage as potential best practices. The PJM Interconnection, which encompasses portions of dense urban areas in the northeast US, already allowed for some participation of electric storage resources, but its proposal does include substantive changes related to resource eligibility and market operations, including a ten-hour capacity requirement that the storage industry will likely fight.

Other regional grid operators submitted proposals that provide less certainty regarding timely and sufficient integration of electrical storage. For example, the New York ISO requested an extension to May 2020 to implement compliance, and its proposal arguably fails to provide necessary flexibility in its markets and allow for storage resources to provide all products that are technically feasible. NYISO's proposal has also been criticized by an agency that is developing energy storage policy for the state. The proposals for markets in the southwest US and New England similarly require clarification regarding technical requirements and parameters to ensure barriers to entry for electric storage are removed. The Midcontinent Independent System Operator Inc., which operates markets in the Midwest and some southern states, proposed changes that would take effect in March 2020 but has also stated that it plans to implement more comprehensive market rules for storage in 2019 and 2020 after additional study.

As stated above, implementation is scheduled to commence in December 2019, absent any extension requests. Generally, the first assessments of the plans submitted by the US regional grid operators indicate progress toward compliance. However, as recent data requests to the regional grid operators from FERC staff demonstrate, some gaps remain. Stakeholders will likely raise certain concerns in the ensuing period, such as why the New England operator proposed to restrict the flexibility of storage resources by mandating them to register as exclusively generation assets and concerns regarding the cost to batteries for charging energy (such as whether they will be charged retail or wholesale prices).

US$2,900

Median price per KWh of a battery storage system paired with solar in Q1 2018

Source: GTM Research models

> As the price of energy storage solutions fall, utilities are increasingly including energy storage as a system capacity component in their long term integrated resource plans.

Independent of reforms spurred by Order No. 841, the California grid operator released a straw proposal to use storage as a transmission asset in May 2018. The basis of the proposal, which appears to have significant support, is a framework allowing storage resources to provide regulated cost-of-service transmission and concurrently providing market-based services (collecting market revenues). By doing so, storage assets would be far more flexible and able to assume a broader range of services, ostensibly while lowering ratepayer-incurred costs.

Several years earlier, FERC decided that storage developers could elect to be compensated in the generation markets or as transmission assets — however, the designation would be mutually exclusive. Double-dip issues with storage simultaneously receiving cost-based and market-based revenue streams were the main concern. The California proposal avoids having to forever forego a particular value proposition, so is flexible in that way, but doesn't allow a storage unit to simultaneously provide all the benefit it can provide, so is inefficient and may stifle investment revenue streams.

State-level regulations and policies are shifting to accommodate battery storage as well. On the market side, for example, California created a product aimed at valuing the capabilities of storage when paired with solar or wind generation; on the consumer side, Maryland recently launched a tax incentive for the installation of storage systems.

Energy storage projects can potentially offer additional services and collect additional revenues, albeit with higher uncertainty. Investment in pure-play storage projects incurs a measure of risk. However, if a project is able to provide ancillary services beyond its contractual obligations (known as value stacking), there is an opportunity for extra cash flow. If a storage facility uses value stacking in addition to supplying contracted capacity, the increased burden may degrade the system or alter its operating profile. Ultimately, developers and consumers can arrange innovative contract designs to best use the services that energy storage can offer.

Regulators can stimulate demand with procurement targets, IRP processes

Independent of federal action, a number of states are pursuing aggressive storage goals, including California, Arizona, Massachusetts, New Jersey, New York, Nevada and Oregon. New York is aiming for three gigawatts of storage by 2030, though following their plan submitted

Sample RFP landscape in the US

State	MWs of storage IRPs	Utility highlights
Arizona	At least 707 MWs	Arizona Public Service Company's (APS) 2017 IRP selected 507 MWs of energy storage resources as cost-effective through the year 2032. APS's IRP concluded that large-scale energy storage applications are more cost-effective than distributed storage. Tucson Electric Power Company's (TEP) 2017 IRP reference case plan assumes the implementation of a 50 MW battery system in 2019, an additional 50 MW battery system in 2021 and a 100 MW battery system in 2031. TEP states in its IRP that it is tracking technology advances in flow-based energy systems (e.g., vanadium, iron, zinc, and Redox Flow technologies) as well as the progress of western pumped hydro storage projects.
California	At least 1,586 MWs	The preferred portfolio in Southern California Edison's (SCE) IRP for the 2017 – 2018 cycle selected 1,586 MWs of additional battery storage resources in 2029 – 2030. SCE's preferred portfolio also states that approximately 9.6 GWs of energy storage will be needed in the entire CAISO system by 2030, to help meet California's 2030 GHG emissions goal.
Florida	At least 50 MWs	Florida Power & Light Company's (FPL) 2018 Ten Year Power Plant Site Plan (Site Plan) includes up to 50 MW of additional battery storage pilot projects for deployment between 2018 and 2020. The pilot projects include battery storage projects paired with existing photovoltaic facilities as well as a 10 MW battery storage project for downtown Miami intended to address distribution system challenges.
Indiana	At least 500 MWs	Indianapolis Power & Light Company's (IPL) 2016 IRP base case selected 500 MWs of energy storage over a 20-year window, with the majority of storage capacity allocated toward the latter part of the 20-year window.
Kentucky	At least 10 MWs	Kentucky Power Company's (KPCo) 2016 IRP calls for a lithium-ion battery storage resource in 2025.
Oregon	At least 39 MWs	Portland General Electric's (PGE) 2017 energy storage proposal, based on its 2016 IRP, calls for US$50 to US$100 million to deploy storage projects that include a 4 – 6 MW transmission-connected storage device, PGE-controlled residential behind-the-meter storage projects, and a substation-sited large-scale storage project.
Washington/ Idaho/Oregon	At least 80 MWs+	Puget Sound Energy's (PSE) 2017 IRP selected 50 MWs of energy storage through 2023 and an additional 25 MWs through 2027 and beyond. PSE particularly found flow batters to be economical for inclusion in its IRP. Avista Corp.'s (Avista) 2017 IRP preferred resource strategy includes 5 MWs of energy storage by the end of 2029.

under FERC Order No. 841, progress may be slower than anticipated. The New York grid operator did not carve out the ability for storage to participate dually in the wholesale and retail markets. However, in February 2019, New York's investor-owned utilities did submit implementation plans for competitive direct procurement processes to secure full dispatch rights from newly qualified energy storage systems for terms up to seven years. Submission of the implementation plans demonstrate forward progress by New York utilities to meet the state's storage goals.

The mechanism for each state target varies: For instance, California is requiring its utilities to procure 1.3 gigawatts of storage resources by 2020. Bills establishing tax credits for behind-the-meter battery storage have been introduced in the state legislatures of Hawaii, New Mexico and Virginia.

In some states, there are regulatory incentives to pair storage with new or existing renewable generating assets. For example, Arizona Public Service started a program to build 2 MWs of distributed generation (solar) with storage, plus US$1 million in customer rebates. States with energy storage procurement mandates or goals and states offering incentives for storage deployment are largely located on the US coasts. Deployment of new, advanced energy storage projects is fastest in those states with increased policy and regulatory emphases on energy storage deployment.

Utilities in states facilitating storage are responding with substantial pledges: in North Carolina, the utility Duke Energy plans to invest US$500 million in energy storage resulting in approximately 300 MWs of installations. In New Jersey, the utility PSE&G announced US$180 million to be allocated toward energy storage as a component of its Clean Energy Future program. Utilities in Nevada and Alabama, respectively, are enabling storage assets to be paired as capacity.

As the price of energy storage solutions falls, utilities are increasingly including energy storage as a system capacity component in their long-term integrated resource plans (IRPs). IRPs are prepared by utilities to assess which mix of resources will economically meet forecasted peak energy demands over a future time horizon, which could stretch as far as the next 20 years. IRPs guide utility choices on the types of resources that utilities should build or own themselves, versus those resources that should be procured from third parties, or those resources that should be deprioritized as not cost-effective. Utilities in at least 15 states have included energy storage in their IRPs.

Faced with the reality of rebuilding Puerto Rico's electric grid after the devastation of Hurricanes Maria and Irma, the Puerto Rico Electric Power Authority (PREPA) recently unveiled the initial draft of its 2019 IRP. PREPA's IRP focuses on organizing "MiniGrids," which are resiliency zones that segregate the PREPA system during major weather events so that local resources can serve load and facilitate timely event recovery. The IRP is in part designed to shift Puerto Rico away from relying upon centralized generation resources in southern portions of the island to relying upon additional decentralized generation resources located across all portions of the island. The draft IRP recommends maximizing the solar PV generation installation rate by issuing requests for proposals (RFPs) in 250 MW blocks with a goal of interconnecting 750 to 1,200 MWs of new solar generation during the first four years (2019 to 2022) of the 20 year planning horizon. The draft IRP also recommends pairing the RFPs with requests for blocks of energy storage and ultimately recommends the installation of 500 to 1,100 MWs of additional energy storage over the same four-year time horizon. Depending on the selected IRP scenario, PREPA's energy storage plans could dwarf those of most other US utilities.

Ultimately, targeted subsidy programs incent investment by utilities and storage developers. However, regulatory bodies should be judicious in deploying such mechanisms so as to avoid overreliance on the subsidies, effectively distorting markets and restricting competitive growth of electric storage resources. The incentives can stimulate such an emerging market particularly as investors and lenders understand the value proposition of storage projects but should not be the long-term foundation.

Subsidies inevitably introduce a level of political risk into the market. Experience in renewable markets, e.g., Spain, should be considered carefully. There, an overreliance on subsidies resulted in widespread project default when subsidies were suddenly withdrawn as a consequence of general budgetary constraint, shaking investor confidence for a significant period.

75%

The minimum required for onsite solar generation for a commercial storage installation to be eligible for the Investment Tax Credit

> **With more states carving out specific goals for storage, their respective RFPs for large solar and/or wind projects are likely to include requirements for electric storage.**

Deepen ties with renewable surge

The symbiotic relationship between renewable, intermittent resources and storage has been slow to develop in both developed and developing countries across the globe. For developed countries, the priority is to pair the growing renewable generation sector with storage; to this point, however, the costs of scaling have exceeded the potential return, thereby stifling interest and investment. As large solar and wind farms become more prevalent, the attendant demand for onsite storage projects to harness that generation will rely on cost-competitiveness. Developing nations, on the other hand, may be more likely to require demonstrations and pilot projects prior to full deployment, or the policies that encourage storage. The World Bank also points out that batteries in some developing nations will need to be particularly resilient to external forces such as extreme weather events and harsh conditions. However, in developing markets, quite often the transmission distribution infrastructure is not well developed or reliable, which can heighten the importance of storage to microgrid systems using renewable generation as a backbone.

In the US, the lag in widespread consumer adoption may be due in part to uncertainty as to whether energy storage facilities can be deemed "qualified energy property" for purposes of the federal investment tax credit. However, in March 2018, the IRS issued a private letter ruling stating that battery installations to a solar photovoltaic system would be eligible for the full 30 percent investment tax credit. The IRS stipulates that any battery storage must be 100 percent powered by the solar system. Nonetheless, this recent clarification offers a clear incentive and opportunities for solar-plus-storage projects due to the certainty of recovering investment costs.

The US Congress extended the federal Investment Tax Credit (ITC) in 2015, largely to bolster the deployment of solar energy. Generally, wind facilities are less likely to pursue the ITC, as the production tax credit

(PTC) is more lucrative and provides a better return on investment due to the larger size of wind projects. In order to qualify for the ITC, the IRS stipulates that residential storage systems (i.e., owned by homeowners and operated on their property) must derive 100 percent of its power from an onsite solar installation (typically in the form of rooftop solar panels). Similarly, the IRS requires commercial storage systems (i.e., owned and operated by businesses) must derive at least 75 percent of its power from onsite solar generation to be eligible for the ITC. In any case, the rates granted to ITC-qualifying projects will be ramped down without further action by Congress: 30 percent until 2019, 26 percent in 2020, 22 percent in 2021, and 10 percent from 2022 onward for new projects.

According to a private letter ruling from the IRS in 2012, new energy storage added to an existing renewable system would be eligible to receive the ITC. In the letter, the IRS established that a wind farm owner could install storage to an operational wind farm. The IRS found the storage device to be part of the "qualified property" at a "qualified investment credit facility" and therefore eligible for the ITC on its full cost. To emulate that approach, the generating resource and storage system must be owned and operated by the same entity or person. Further, in March of 2018, the IRS issued another private letter ruling applying to the installation of energy storage to integrate into an existing residential solar photovoltaic system. The IRS ruled that the new storage device would be eligible for the full tax credit, conditioned on the 100 percent requirement (from the renewable energy source) as described earlier.

To this point, utilities and regulators have not yet matched this trend with planning to keep pace (both for the utilities and for the grid). However, utilities and states are beginning to prepare for the increased penetration of distributed energy resources (DERs). A common approach that is emerging is based on more precise and granular forecasting—utilities will be able to identify customer adoption rates in order to ensure reliability. Regardless, as more DERs are installed, more utilities and grid operators will evaluate how to modernize the grid and compensate these resources appropriately.

> "By integrating energy storage into the grid, nearly all entities with a stake in the electricity market can yield positive returns.

150

corporations are now part of the RE100 initiative

Solar-plus-storage projects are emerging as more viable in certain markets, in large part due to evolving consumer preferences, net metering programs and revisions to utility rate tariffs that carve out provisions for storage. For most residential adopters, however, despite market penetration and economies of scale, the cost of storage systems paired with solar generation is still prohibitively expensive due to its capital-intensive nature. As of the first quarter of 2018, the median price of a battery storage system paired with solar was US$2,900 per kilowatt-hour, according to GTM Research models. The gradual lowering of lithium-ion battery prices may help to reduce the overall expense, however. With the exception of early adopters, these additional costs have mostly limited solar-storage pairings to markets with clear enabling policy environments such as California (Self-Generation Incentive Program) and Hawaii (Customer Self-Supply Program).

The state of Hawaii has led the charge in arranging solar-plus-storage power purchase agreements. This may be somewhat attributable to high electricity costs (the highest in the US, due to the proportion of imported conventional fossil fuel resources) but has been buttressed by a commitment to deploy electric storage installations alongside solar generation at both the utility and residential levels. Hawaii's goal of achieving 100 percent renewable resources by 2045 also spurs the solar-plus-storage boom.

Finally, many recent offshore wind solicitations in the US have specifically included a requirement for electric storage (via batteries) and transmission. For instance, all three proposals selected in the Massachusetts offshore wind round earlier this year included either battery or hydroelectric storage as part of the project. With more states carving out specific goals for storage, their respective RFPs for large solar and/or wind projects are likely to include similar requirements. The 300 MW RFP in Hawaii held in early 2018, and scheduled for installation by 2022, included both solar and wind, as well as the option to include energy storage in the bidding. In Europe, companies have already installed storage with offshore wind farms amid efforts to further develop the market.

Make the case for corporate buyers of renewable power to integrate storage options

Commercial barriers to electric storage deployment in the US are fading rapidly. As is common with many innovative technologies, the adoption curve is broadening (due to higher efficiencies in manufacturing and lower bulk costs of materials). The overall supply chain of battery storage is benefiting from economies of scale. Moreover, as markets adapt to integrate these resources, demand will continue to rise, and costs will continue to fall (to a point, as it remains to be seen how competitive storage will be compared to conventional energy resources on a levelized cost basis).

For commercial customers, the dovetailing benefits of renewable generation and storage include a quickly arising need for backup power. In light of more frequent and severe weather events that may disrupt power grids and market operations, the capability for commercial customers to respond without delay, leveraging onsite power held from renewable generating units would be a boon from both an investment and reliability perspective.

Many corporate buyers of power have focused on greening their energy use and minimizing externalities from fossil fuel consumption, despite some institutional barriers to their ability to directly buy green power (e.g., laws that require them to be served by the local utility that may deliver brown power). Currently, two-thirds of Fortune 100 companies have established a corporate renewable energy target. Some corporations, such as Google and Apple, have reached their target of achieving 100 percent greening of load on an annualized basis. More are likely to follow suit, as more than 150 corporations are now part of the RE100 initiative by committing to match 100 percent of electricity used in their global operations with electricity generated from renewable sources, either self-produced or purchased on the market from specific generators, a utility or other supplier, or through purchase of renewable energy certificates.

However, the next progression of corporate renewable energy initiatives is likely to see corporate buyers trying to find ways to power their operations with energy sourced solely from renewable or other carbon-free energy sources at all times, in all places, potentially on a hyper-local region-specific level. For instance, Google recently announced it intends to source enough carbon-free energy to support its operations on a 24-7 basis, explaining that it will "broaden the scope of energy sources to include technologies or services that enable 24-7 clean energy." Microsoft is also investing in its renewable energy portfolio through its proxy generation power purchase agreement, which will support its goal of matching renewable energy generation with its consumption on an hourly basis.

In either case, however, doing so presents a number of market and operational challenges, given the variability of renewable sources and the geographic limits on the types of renewable sources available. It is often the case that the amount of available renewable generation capacity is insufficient to meet the load requirements at a particular time. Energy storage therefore is poised to play a critical role in overcoming these challenges, particularly when paired with utility-scale solar projects. The expected decline in battery storage costs will mean that solar-plus-storage projects are becoming more economically viable. Pairing storage with solar will provide a way to inject energy into the system at times when solar production may be low or during peak demand times. As such, energy storage systems can improve system reliability and minimize the need for corporate or industrial consumers to use traditional fossil fuel sources to meet their operational requirements.

Recent high-profile deals demonstrate a growing commercial interest in combining renewable energy with electric storage. In 2016, Tesla announced US$2.6 billion plans to purchase SolarCity, and Total (which owns a controlling stake in the solar panel maker SunPower) agreed to acquire Saft (a French battery company) for US$1.1 billion.

Conclusion

The landscape of electric storage is approaching real market parity, partly due to innovation and economic forces, but just as much due to the deliberate attention of policymakers and regulatory bodies around the world. For decades, storage has been regarded by policymakers and grid operators as the "next step" to achieving a modern energy system that adapts to technology and consumer preferences. The cascading positive effects of new targets, specific rules and design, and corporate engagement and investment should beget a substantial rise in storage deployment. Dovetailing with steady growth and incremental improvements is a need for market participants to continually evaluate how to optimally deploy projects without disrupting power markets. In any adoption curve, a new technology presents the risk of unintended consequences and uncertainty. The outlook of integrating energy storage into the grid, though, appears almost universally beneficial. Nearly all entities with a stake in electricity—from residential customers to corporate investors to the utilities and regulators—can yield positive returns in the form of a stronger, quicker grid or reduced costs. With that outcome in mind, the pursuit of electric storage is poised to convert from a long-term idea to near-term action and results.

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