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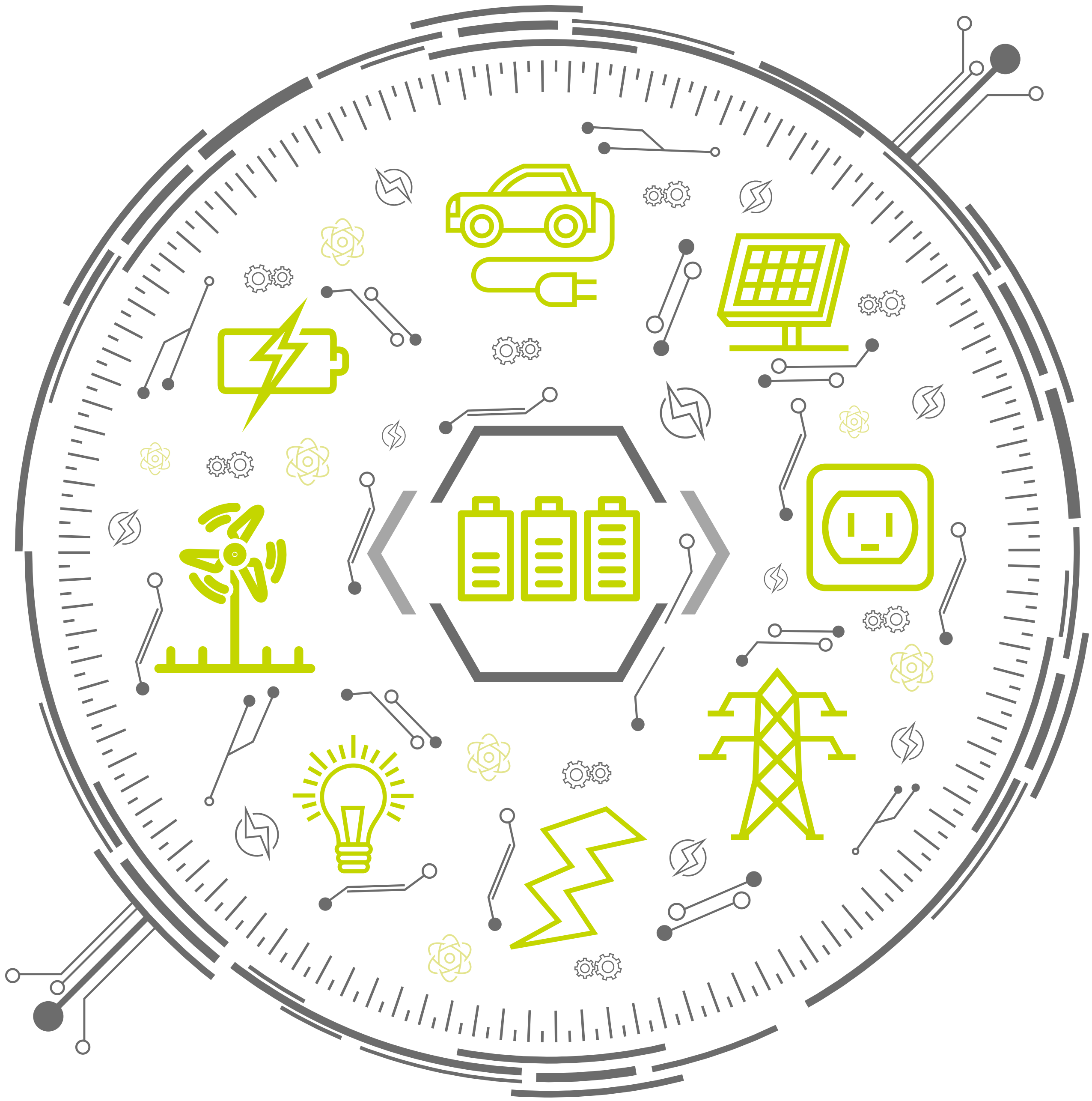

Supercharged: Challenges and opportunities in global battery storage markets

Deloitte Center *for* Energy Solutions

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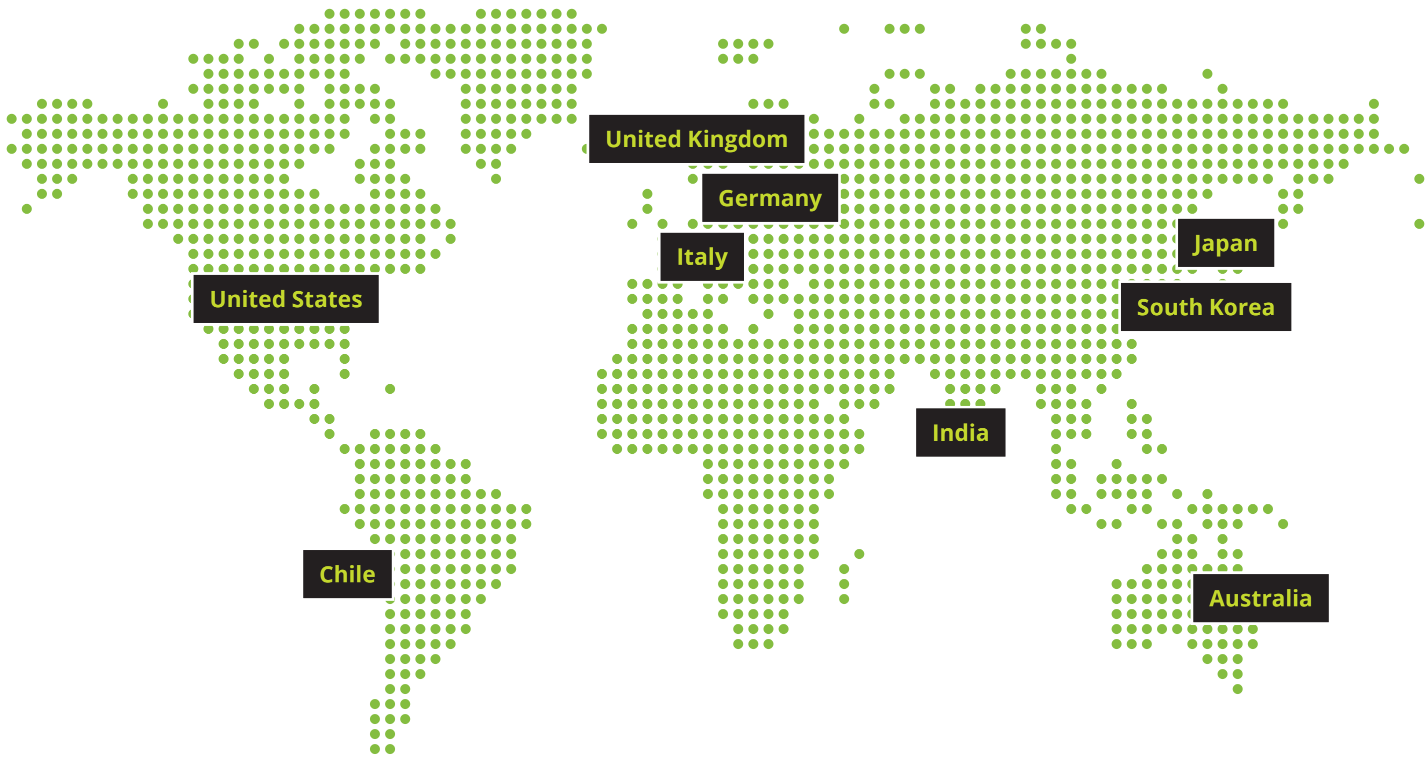


Executive summary

This report examines how some of the nations that are more actively modernizing their electric power grids and adding renewable energy are approaching energy storage. Particularly focusing on battery storage in electric power grids, we sought to uncover what is driving the push for energy storage and what utilities, policymakers, and other stakeholders are doing to develop storage markets and support ongoing deployment. Our findings revealed a broad range of market drivers and remaining barriers, but they also revealed a commonality: the pace of product deployment and market development is accelerating.

Battery storage is flexible, can be deployed quickly, has multiple applications, and can produce numerous value streams—not to mention that battery prices are falling faster than anticipated. However, the dynamism in the sector is not solely attributable to these factors.

Advances in adjacent digital technologies, such as artificial intelligence, blockchain, and predictive analytics, are giving rise to aggregated solutions and innovative business models that were nearly inconceivable a few years ago. Start-ups around the world are rapidly commercializing intelligent networks of "behind-the-meter" batteries to benefit electricity customers, utilities, and grid operators.

Our analysis provides a global view of how much progress has been made in the area of aggregation as well as in other forms of battery solution development and deployment. It also provides utilities, independent power producers (including renewable energy companies) and other stakeholders in the energy value chain with insight into global trends in battery storage, particularly what is working well, what is not, and what challenges still remain.

Introduction

Depending on which analysis one reads, the global market for energy storage is poised to grow rapidly, but few can agree on how much. According to one widely publicized projection, the storage market could reach more than $26 billion in annual sales by 2022, a compound annual growth rate (CAGR) of 46.5 percent.[1] Another analysis envisages growth at a more modest, but still robust, pace, expanding at a compound annual growth rate of 16 percent and reaching $7 billion annually by 2025.[2] Others put it somewhere in the middle, while a few take a slightly more optimistic or pessimistic view.

The divergence of opinions largely originates with how one defines energy storage. Some analyses calculate only "front-of-the-meter" utility-scale technologies, while others include "behind-the-meter" solutions implemented by commercial and industrial (C&I) customers. And others include electric vehicle batteries and smaller scale battery-plus-solar combinations implemented by residential consumers, which could have not only behind-the-meter applications but also front-of-the meter uses if they are controlled by aggregators or utilities. Complicating the picture even more are the many applications for energy storage, which can be useful in integrating renewables, supporting smart grids, creating more dynamic electricity markets, providing ancillary services, and bolstering both system resiliency and energy self-sufficiency.

Despite the complexity of the landscape, many growth projections agree that energy storage is gaining traction around the world and could fundamentally change market dynamics. To understand these shifting dynamics, we peered beneath the aggregate growth projections to examine how some of the more active nations in renewable development and grid modernization are now approaching energy storage.

These countries include Australia, Chile, Germany, Japan, India, Italy, South Korea, the UK, and the US. Particularly focusing on battery storage, which is presently the leading technology, our examination sought to uncover what has been driving the push for energy storage in these nations and what utilities and policymakers have been doing to define battery storage, develop storage markets and to support ongoing deployment.

In presenting our findings, we begin by exploring key market drivers for battery storage.

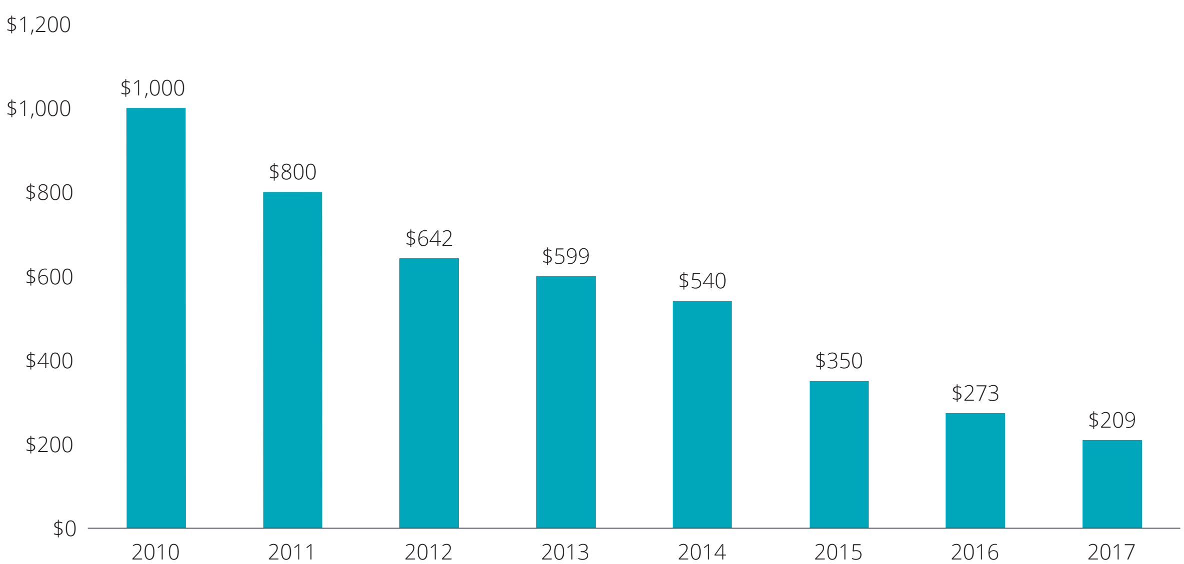
Photo courtesy of Tesla, Inc.

Market drivers

Driver 1: Cost and performance improvements

Energy storage in various forms has been around for decades. This begs the question: why battery storage and why now? Perhaps the most obvious answer is declining costs and improved performance, particularly relating to lithium-ion batteries, since expanding electric vehicle markets are promoting manufacturing economies of scale. As illustrated in Figure 1, costs for lithium ion batteries are declining at a steep trajectory. However, in examining the nine nations in our analysis, it became apparent that declining costs are only part of the story.

Figure 1. Lithium-Ion battery prices fell 80% from 2010-2017 ($/kWh)



Source: Bloomberg New Energy Finance, Lithium-ion Battery Price Survey

Note: The survey provides an annual industry average battery (cells plus pack) price for electric vehicles and stationary storage. Stationary storage developers paid about $300/kWh for battery packs in 2017— 51% more than the average automaker price of about $199. This is typically due to much lower order volumes.

Driver 2: Grid modernization

Many developed countries are embarking on grid-modernization programs to boost resilience in the face of severe weather events, reduce system outages linked to aging infrastructure, and improve the overall efficiency of the system. These programs often involve deploying smart technologies within established electrical grids to enable two-way communication and advanced digital control systems, along with integrating distributed energy resources (i.e., renewables, fuel cells, diesel or natural gas generators, storage assets, and microgrids).

In general, we found the growth of battery storage goes hand-in hand with grid modernization efforts, including the transition to smart grids. Digitizing the grid enables prosumer participation,[3] intelligent system configuration, predictive maintenance, and self-healing, and it paves the way for the implementation of tiered rate structures—all of which create opportunities for batteries to generate value by adding capacity, shifting load, and/or improving power quality. While smart technologies have been around for some time, batteries help to unlock their full potential, and vice versa.

Tesla, in conjunction with Neoen, recently completed the world's largest lithium-ion battery installation (100 MW) in South Australia.[4] After an outage in 2016 that caused 1.7 million residents to lose power, the state of South Australia commissioned the battery as part of a larger grid-modernization effort to help address supply shortfalls, soaring prices, and concerns over system reliability and resilience.[5] The giant battery installation stores excess energy from the nearby Hornsdale wind farm during off-peak times and discharges it back into the grid to correct supply and demand imbalances and to provide fast-response emergency power during outages.[6]

Driver 3: Global movement toward renewables

Broad support for renewables and emissions reduction is also driving adoption of battery storage solutions. The critical role that batteries can play in offsetting the intermittency of renewables and reducing curtailment is well known, but the strength and pervasiveness of the desire for clean energy among all types of electricity customers is growing. This is especially apparent within the corporate and public sectors. As noted in the recent Deloitte report, *Serious Business: Corporate procurement rivals policy in driving the growth of renewable energy*, large multinational corporations have taken a leadership role in procuring renewable energy around the globe. Indeed, many have publicly pledged to reach 100 percent renewable energy in the next two decades or sooner through programs such as RE100 and the Renewable Energy Buyers' Alliance.[7] This bodes well for continued renewable development and, presumably, for continued deployment of batteries to assist in integrating greater amounts of distributed energy resources.

A new technology for integrating battery systems into solar plants has the potential to boost their energy output. Florida Power & Light Company is piloting the innovative DC-coupled battery system at its Citrus Solar Energy Center.[8] By capturing energy that exceeds inverter capacity when the sun's rays are strongest, the battery system has the potential to harness millions of kilowatt-hours of surplus solar energy a year that would normally be lost, thus improving both the quantity and predictability of the plant's output.[9] Increased predictability, in turn, enables the utility to more efficiently dispatch other power plants, helping customers to save on energy costs.[10]

Driver 4: Participation in wholesale electricity markets

Though renewables and batteries are often mentioned in the same sentence, battery storage can help balance the grid and improve power quality regardless of the generation source. This points to a growing global opportunity for batteries to participate in wholesale electricity markets. Within our analysis, nearly every nation is revamping its wholesale market structure to allow batteries to provide capacity and ancillary services, such as frequency regulation and voltage control. These applications are still nascent and are finding varied success as policymakers work to remove barriers to storage participation and markets recalibrate.

Take Germany's primary control reserve (PCR) market for example. Participants in this market generate revenue by winning a weekly auction and receiving remuneration for providing capacity to balance the grid.[11] While the PCR market has been open to storage providers for the past few years, battery deployment did not become significant until 2016, when declining system costs allowed for a viable return on investment.[12] Unlike conventional generators, batteries are able to respond to system imbalances almost instantaneously, becoming fully activated in less than the required 30 seconds.[13] However, because there is no remuneration for fast-response in Germany as there is in the US, battery providers compete directly against established incumbents such as gas peaker plants. On one hand, this undifferentiated competition has been effective in driving down the cost of capacity, but on the other, it has led to rapid market saturation, thin margins, and an uncertain economic situation for battery storage providers. With little room to grow in the PCR market, battery solution providers in Germany are increasingly setting their sights on the secondary reserve market and distribution deferral as potential new value streams.[14]

As in Germany, some grid operators in the US have also allowed batteries to compete in their systems.[15] The opening of US wholesale electricity markets to providers of fast-responding resources such as batteries and flywheels can largely be attributed to Federal Energy Regulation Commission (FERC) Orders 755 and 784, issued in 2011 and 2013, respectively.[16] These Orders specified that speed and accuracy must be rewarded in ancillary services markets.[17] Since inviting battery providers to participate in frequency regulation markets, grid operators have been challenged by some initial imbalances in the mix between fast-ramping and slower ramping resources and matters related to dispatch parameters, signals, and other technical requirements. However, moving ahead, our findings suggest that the benefits of integrating batteries into wholesale electricity markets can outweigh these growing pains, since policymakers around the world are increasingly taking action to reward the contributions fast-acting batteries can make to balance grid operations. For instance, Chile's national energy commission has drafted a new regulatory framework for ancillary services that recognizes the contributions that battery storage systems can provide.[18] Italy too has opened its ancillary services market to pilot renewable energy and storage projects as part of sweeping regulatory reform efforts.[19] And, on February 15, 2018, FERC issued a final rule on taking further steps to remove barriers to the participation of electric storage resources in the capacity, energy, and ancillary services markets subject to its jurisdiction.[20]

The President of Chile, Michelle Bachelet, has introduced a new long-term national energy strategy that sets a goal of generating at least 70 percent of the nation's electricity from renewable sources by 2050.[21] In support of integrating more renewables into the country's electrical grid, the national energy commission in Chile has drafted new ancillary services regulations that would make energy storage part of its regulated system and pave the way for battery technologies to offer rapid frequency response services.[22] The regulatory updates have caught the attention of battery manufacturers, some of whom are now eyeing the market not only to take advantage of the ancillary services opportunity but also to provide infrastructure for mitigating transmission bottlenecks and for storing the output from the country's abundant solar and wind plants. For instance, NEC has already deployed several projects in Chile, and Siemens intends to enter the market with an innovative hybrid natural gas and lithium-ion battery solution developed by Fluence, its new joint venture with AES.[23]

Photo courtesy of San Diego Gas & Electric

Driver 5: Financial incentives

The widespread availability of government-sponsored financial incentives in the nations we researched further reflects policymakers' growing awareness of the range of benefits battery storage solutions can deliver throughout the electricity value chain. In our research, these incentives ranged from a percentage of battery system costs being refunded directly or through tax rebates, to capital support through grants or subsidized financing. These incentives appear to be particularly generous in countries that have energy security concerns, such as Italy which offered a 50 percent tax deduction in 2017 for residential storage installations,[24] or in nations that have an economic stake in battery manufacturing such as South Korea, where government-supported investment in energy-storage systems has expanded their output to 89 megawatt-hours (MWh) for the first half of 2017, up 61.8 percent compared to the same time the previous year.[25]

With the stated objectives of integrating more renewables and improving grid reliability, the South Korean Ministry of Trade, Industry and Energy expects to invest US$391.6 million in new energy storage systems from 2017-2020.[26] The investment will be carried out via incentives that give operators who install energy storage systems alongside their utility-scale solar plants additional points on the assessment of their renewable energy certificates.[27] Of note, South Korea is home to several domestic battery producers, including Samsung SDI, LG Chem, and Kokam.[28] The energy storage incentive is part of a broader plan by the South Korean government to pump US$27 billion into renewable energy from 2017-2022.[29]

Driver 6: Phase-outs of FITs or net metering

Low or declining feed-in-tariffs (FITs) or net metering payments additionally emerged as a driver of behind-the-meter battery deployments, as consumers and businesses seek ways to obtain greater returns from their solar photovoltaic (PV) investments. This is occurring in Australia,[30] Germany,[31] and the UK[32] as well as in Hawaii[33] within the US. These areas have some of the most mature solar markets, partly because electricity prices are high enough to make solar economically viable. While this is not yet a global trend, it is reasonable to think it may become one as FITs phase down in more nations and as the owners of solar PV installations look to batteries as a means of self-consuming more of the electricity they produce, shifting their loads to avoid peak charges, and/or providing grid-stabilization services by allowing a utility or an aggregator to charge or discharge their batteries when needed. For instance, residential storage permits in Honolulu, Hawaii, grew by 1,700 percent, or 18-fold, in 2017. This surge was partly due to the elimination of the state's net metering policy in 2015 and caps on participation in subsequent incentive programs for sending electricity back into the grid.[34]

Driver 7: Desire for self-sufficiency

While the aforementioned drivers have been well-documented, a growing desire for energy self-sufficiency among residential and C&I customers emerged as a somewhat surprising force behind storage deployment. This desire is fueling behind-the-meter markets to some extent in nearly every country we examined, suggesting that the motivations for purchasing storage systems are not purely financial.

In Germany, for example, ecological motives, independence from utilities, resiliency and technical curiosity are all thought to be motivations.[35] Similarly, self-sufficiency is a strong driver in Italy, the UK, and Australia.[36,37] The latter, in particular, is experiencing an unprecedented residential storage boom, driven by a combination of falling battery prices, regulatory changes, and a desire to be self-reliant.[38] Some Australians perceive their regional electric grids to be unreliable, and they see battery-plus-solar systems as a way to ensure they have adequate power supply. Seven thousand batteries were installed in Australian homes in 2016, and that figure was expected to more than quadruple, reaching upwards of 30,000 homes in 2017 (final 2017 audit figures were not yet available at the time of this writing).[39] As mentioned previously, the expiration of residential solar FITs is the likely motive behind some of these installations, with about half being retrofits or add-ons to existing solar PV installations.[40] The other half, however, are brand new solar-plus-storage systems that are not necessarily linked to the FIT phase-outs.[41] With large residential battery systems still costing between AU$8,000 and AU$10,000 (US$6,300-8,000), the likely motives are self-sufficiency and the pride of being an early adopter, rather than rapid payback and return on investment.[42] While battery storage systems have to be cost-competitive, their popularity in Australia, along with our findings elsewhere, suggests they do not necessarily have to be significantly less expensive than purchasing electricity and services from a utility in order for the market to grow.

Driver 8: National policy

Additional opportunities for battery storage providers are arising from national policies aimed at furthering a variety of strategic objectives. Many countries see renewables plus storage as a new way to lessen their dependence upon energy imports, fill gaps in their generation mix, enhance the reliability and resiliency of their systems, and move toward environmental goals and de-carbonization targets. Some nations, such as Italy and Japan, are actively subsidizing and promoting energy storage as part of broad restructuring efforts, aimed at ensuring reliability and reducing dependency on international energy companies and foreign imports.

Energy storage will also likely benefit from broad policy mandates linked to urbanization and quality-of-life goals in developing nations. For example, India's Smart City Initiative uses a competitive challenge model to support deployment of smart technologies in 100 cities throughout the country.[43] Among the objectives for these deployments are assuring adequate electricity supply, environmental sustainability, efficient mobility, and public transport.[44] Electric vehicles, renewable energy, and battery storage are all critical to attaining these objectives—as evidenced by the announcement from the Indian government that the nation aims to start selling only electric cars by 2030.[45] In addition, the government is targeting 100 gigawatts (GW) of solar energy capacity by 2022, up from around 10 GW in 2016.[46] The recent launch of India's first grid-scale battery storage system, which was designed for peak-load management, hints at a potential boom for energy storage as the nation seeks to realize its aggressive policy objectives, which largely hinge upon developing a clean, reliable electricity system.[47]

Following the 2011 Fukushima Daiichi nuclear accident, Japan found itself highly dependent on fossil fuel imports after shutting down its nuclear fleet due to safety concerns. In response, the Japanese government overhauled its national energy policy, emphasizing regional self-sufficiency and energy diversification through acceleration of renewable deployment, as well as revitalization and economic competitiveness through innovation and technology development.[48] This included setting an explicit target of capturing 50 percent of the world's projected global battery storage market by 2020, as outlined in its 2014 Strategic Energy Plan and in the 2014 revision of the Japan Revitalization Strategy.[49]

Japan's commitment to maintaining technological leadership is one of the reasons the nation has aggressively pushed forward with domestic deployment of battery storage, despite an abundance of pumped hydro storage capacity, which became available in the wake of the nuclear shutdowns.[50] Today, Japan is home to one of the world's largest battery storage testing facilities;[51] generous government-subsidies for grid-scale battery deployment;[52] and numerous cutting-edge pilot projects, including recently announced projects with California-based storage providers, Stem Inc. and Sunverge Energy.[53] The Stem initiative involves deploying a "virtual power plant," composed of aggregated storage systems that will supply 750 kilowatt hours (kWh) of capacity to the grid.[54] The Sunverge Energy effort involves installing dozens of energy storage units to help make the grid more reliable.[55] Both projects will be conducted in conjunction with the domestic conglomerate, Mitsui & Co., and they support Japan's push to increase the proportion of renewables in its generation mix.[56]

Challenges

Though market drivers are converging to propel storage deployment forward, challenges still exist. The more prominent barriers can be traced to the speed with which battery storage technologies and their applications are evolving, and to the multiplicity and flexibility of battery storage.

Barrier 1: Perceptions of high prices

Like any technology, battery storage is not always economical, and costs will often be too high for a particular application. That is to be expected. The problem is that inaccurate perceptions of high costs can block batteries from being considered in the solution set. Costs have been dropping so quickly (see Figure 1) that decision-makers may have outdated notions about the price of systems, thinking that batteries still cost the same as they did a couple of years ago, or even six months ago. Declining battery prices, and their impact on overall system costs, were recently and dramatically illustrated by an Xcel Energy solicitation, which attracted a median price of $36/MWh for solar-PV-plus-batteries and $21/MWh for wind-plus-batteries.[57] The solar-plus-battery price set a new record in the US and that may not stand long.[58]

Price declines are expected to continue, both regarding the cost of the battery technology itself as well as of balance-of-system components. Although these supporting technologies do not generally garner as much press attention, they are just as important as the batteries themselves, and they could represent the next big wave of cost reductions. Inverters, for instance, are "the brains" of a storage project, and they significantly influence project performance and returns. However, according to a recent report from GTM Research, the market for inverters is still "nascent and fragmented, full of new products with varying applications and functionality."[59] Thus, the prices for storage inverters are expected to fall over the next few years as the market matures and the landscape consolidates.

Photo courtesy of Tesla, Inc.

Barrier 2: Lack of standardization

Participants in early stage markets often have to contend with diverse technical requirements as well as varied processes and policies. Battery suppliers are no exception. This disparity adds to complexity, and therefore costs, throughout the value chain, making lack of standardization a significant roadblock to further deployment. Standardization could be particularly important to the proliferation of battery storage because of "balance of charge" issues associated with batteries. In other words, they can't be discharged too far or it will damage the units; network operators need to know how much "juice" is left in a battery at a given time; and recharge/cycle times are different depending on the type of battery employed (for example, flow versus solid-state, as in lithium-ion).

Barrier 3: Outdated regulatory policy and market design

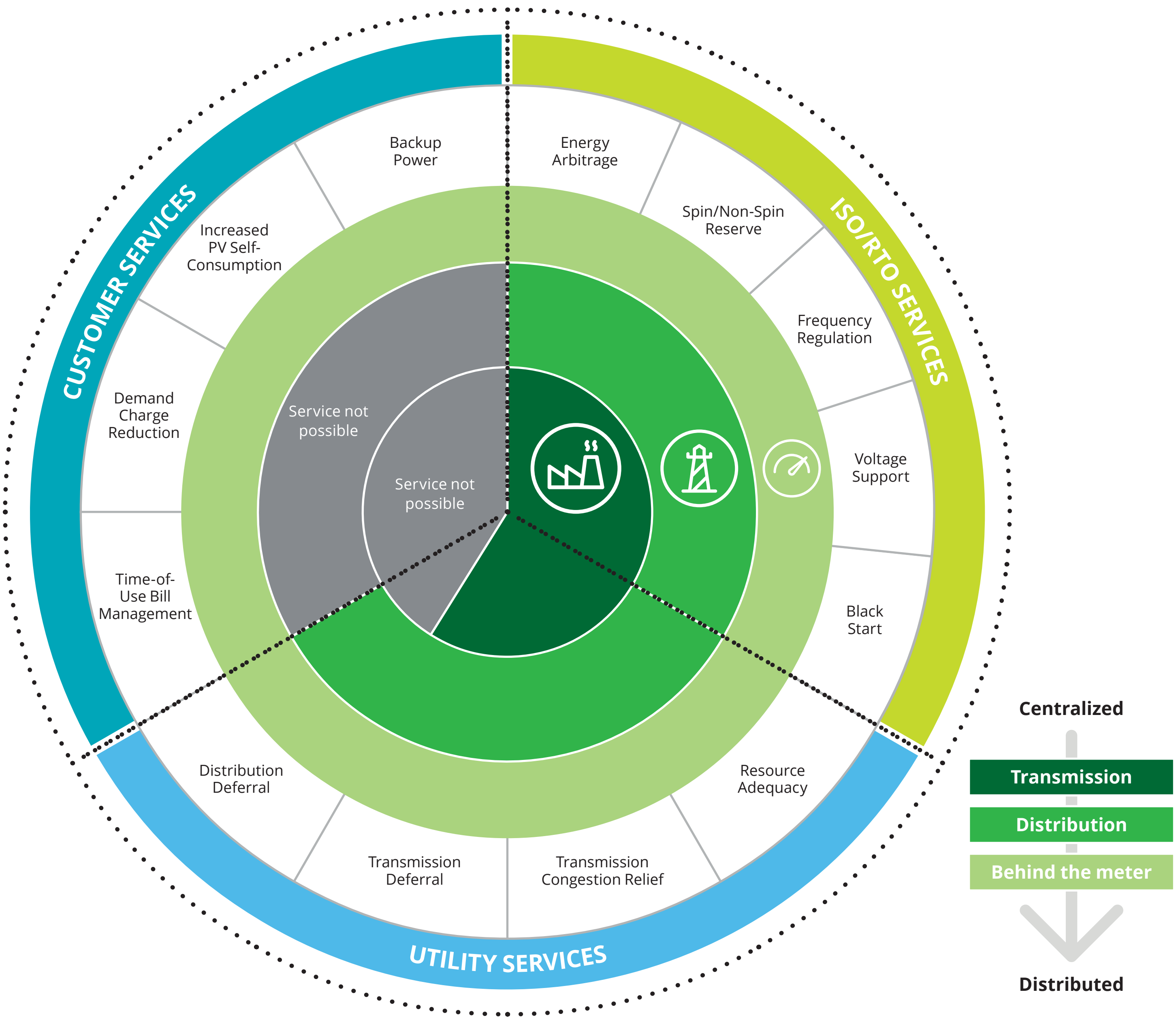
As can be expected with emerging technologies, regulatory policy is lagging the energy storage technology that exists today. A statement from the Edison Electric Institute, an association that represents US investor-owned electric companies, summarizes the situation: "Many public policies and regulations must be updated to encourage the deployment of energy storage. Current policies were created before new forms of energy storage were developed, and they do not recognize the flexibility of storage systems or allow them a level playing field."[60] One regulatory construct that may need to change is to enable storage to be classified as generation, load or transmission and distribution infrastructure, so as optimize use of this "uniquely flexible resource."[61]

Lagging policies are not news to regulators and system operators. As mentioned previously, many are working to update ancillary services market rules to support storage deployment. The capability of battery storage systems to enhance the flexibility and reliability of the grid has been well documented, which is perhaps why regulators tend to focus first on wholesale markets. However, retail rules will also need to be updated, especially as residential and C&I interest in energy storage systems grows. To date, the discussion in this area has been mainly about implementing tiered or structured rates enabled by smart meters and based on time-of-use. Without tiered rates, battery storage loses one of its most attractive attributes: the ability to facilitate rate arbitrage by storing electricity when it is cheap, and selling it when it is expensive. Time-of-use rates have yet to become globally prevalent, but this situation could change quickly as smart meter rollouts are completed in a number of countries. Policymakers in the UK, for instance, have already made some basic time-of-use tariffs available, designed based on either seven or ten off-peak hours, predominantly during night time.[62] These tariffs are likely to become more sophisticated and more widely adopted in the future when a nationwide roll-out of smart meters is completed in 2020.[63]

Barrier 4: Incomplete definition of energy storage

A lingering barrier to energy storage adoption is rooted in lack of familiarity with the full range of applications for battery storage solutions, along with an incomplete understanding of how to assign value to them and compensate providers. Put another way, energy storage is having an identity crisis, with stakeholders and policymakers around the world wrestling with how to define fast-acting battery storage. Clearly, this is no easy task. For instance, the Rocky Mountain Institute (RMI) has identified 13 value streams for energy storage across three customer segments—and, this is only one model among many (See Figure 2).

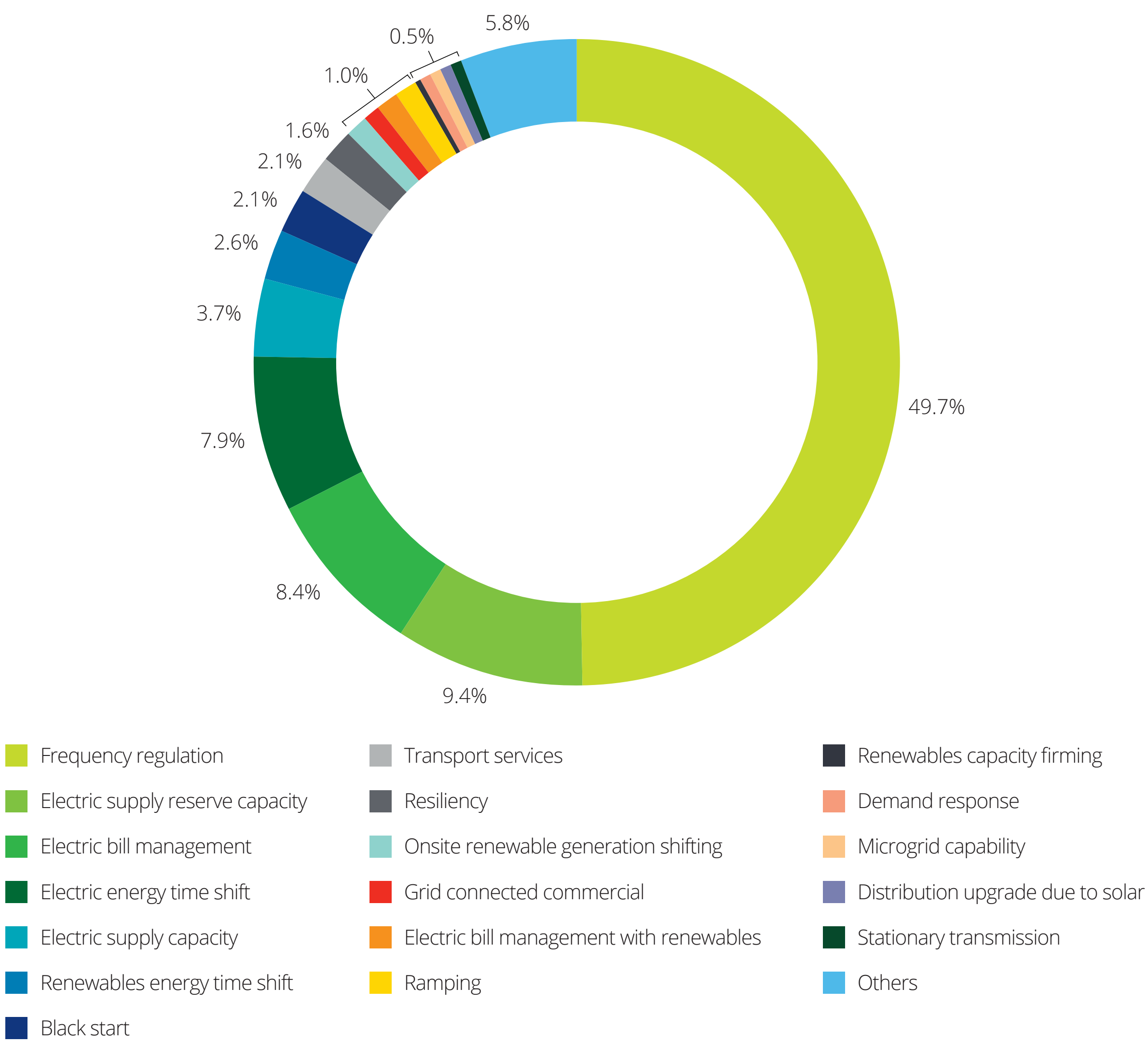
Figure 2. Energy storage value streams



Source: Mandel and Morris, "The Economics of Battery Storage", Rocky Mountain Institute

Globally, the most common use for battery storage is frequency regulation, followed by reserve capacity, bill management, and energy time shifting (see Figure 3).

Figure 3. Global battery storage capacity by primary use case



Source: *Electricity Storage and Renewables: Costs and markets to 2030,* International Renewable Energy Agency (IRENA), October 2017, p. 33, http://www.climateactionprogramme.org/images/uploads/documents/IRENA_Electricity_Storage_Costs_2017.pdf

While stakeholders may not agree on how to define energy storage, they seem to concur that the growth of storage markets boils down to making sure providers are compensated for the full range of services they can provide, also known as "value stacking." A recent report from the Brattle Group cited several barriers to value stacking, or allowing providers to be compensated for providing multiple services at once.[64] Though the report focused on the California market, the authors assert that the barriers are broadly relevant elsewhere in the US and around the globe.[65] These barriers include outdated policies regarding aggregation requirements for wholesale market participation, limits on net exports of energy to the grid, and the need for prioritized dispatch control to provide clarity around which entity has priority to dispatch a battery when it is utilized for more than one purpose by multiple parties.[66] California is the first state to approve rules allowing battery storage systems to generate multiple revenue streams, spanning usage in transmission and distribution as well as generation.[67]

As regulatory authorities grapple with the multiplicity and flexibility of battery storage, some have chosen to set either mandatory or voluntary energy storage targets for utilities within their jurisdictions to purchase certain amounts of energy storage to ensure the reliability of the grid. California was among the first US states to go this route, mandating in 2013 that its three largest investor-owned utilities procure 1,325 megawatts (MW) of electricity storage by 2020.[68] With the utilities well on their way to achieving this goal, the state raised the target in September 2016, directing utilities to procure another 500 MW of behind-the-meter and/or distribution-connected storage.[69] In addition to California, storage targets have been set in Massachusetts, Oregon, and most recently New York.[70] Nevada may follow suit,[71] while Maryland has taken a slightly different tack, launching an energy storage tax credit program in February 2018.[72] Many other states are considering or implementing energy storage incentives, and some state public utility commissions now require that utilities include storage in their integrated resource plans.[73]

California is on the forefront of implementing energy storage systems and other distributed energy resources, having passed the first energy storage mandate in the US in 2013.[74] One of the state's most notable early deployments came in late 2015 when the Aliso Canyon natural-gas storage field experienced a catastrophic leak, jeopardizing gas supplies to critical power plants in Southern California. Responding to an emergency storage tender from state regulators, three storage providers delivered three grid-scale lithium-ion battery projects totaling 70 MW in just six months.[75] This effort helped to build confidence among regulators, system operators and utilities that batteries and solution providers were capable of shoring up grid infrastructure quickly and cost-effectively. Building upon the success of these deployments and several others since then, the California Independent System Operator (CAISO) recently proposed a program to pay energy storage resources for "load shifting," absorbing excess energy from the grid and making it available later.[76] The California Public Utilities Commission is also considering a proposed plan from one of the state's large investor-owned utilities to replace three critical natural gas-fired power plants with energy storage.[77] Though California is one of a few markets where energy storage is competitive with gas-fired peaker plants today, this situation is changing quickly as battery solution providers have more opportunities to prove their cost-effectiveness, flexibility, and responsiveness. Indeed, a recent analysis by GTM/Wood Mackenzie suggests that because of battery storage by 2025 there will be little, if any, need to build gas peaker plants.[78]

In areas without specific targets or mandates, lack of clarity around what energy storage is and how it should be compensated creates a propensity for utilities to remain in "demo" mode with regard to deploying storage.[79] Regulated utilities might pilot a solution to address a pressing need or to show regulators they are exploring battery solutions, but they are not ready to make big bets on large-scale storage programs if they are unsure of the return on their investment or if they have been unable to obtain explicit approval from their public utilities commission to recover investment costs. While mandates are controversial, some stakeholders see them as essential for kick-starting the storage market and providing a path for utilities and providers to learn as they go, rather than waiting for holistic reform of energy policies and missing windows of opportunity in the meantime.

Focal points for storage providers

With the chorus of voices getting louder in favor of revenue stacking, regulators are generally amenable to the concept of better defining energy storage, opening up markets to new participants, and ultimately compensating providers for multiple value streams. However, it can take years to redesign retail and wholesale electricity markets, which has left storage providers searching for ways they can add value and grow in the meantime.

Some storage providers are finding an answer in transmission and distribution deferral, such as the 8 MWh bank of batteries recently proposed by Arizona Public Service and AES Energy Storage (now Fluence).[80] Expected to take only 12-15 months to plan and implement, the system will be deployed in a community northeast of Phoenix as a fast, cost-effective alternative to constructing a 20-mile transmission line.[81] Other storage providers are focusing on niche, high-growth segments such as data centers, and still others see opportunities in deploying storage as part of micro-grids. The impact of climate change and more severe storms has led to a sense of urgency regarding the latter, with storage companies playing a significant role in rebuilding and upgrading the electricity infrastructure on hurricane-ravaged Caribbean islands, both to provide emergency power in the short-term and greater system resiliency in the long run.

Photo by Kenneth Wilsey

Terna, the organization responsible for managing Italy's transmission network, was among the first to realize the potential of battery storage for deferring transmission upgrades. After evaluating traditional infrastructure investments, Terna chose a battery storage system from NGK Insulators, a Japanese provider of sodium sulfur battery technology, to alleviate congestion in transmission lines running north-south in the country and to reduce curtailment of wind generation in the south.[82] Commissioned in 2015, the system stores 245 MWh of renewable generation per day, holding this energy until transmission capacity becomes available and it can be sent to cities further north.[83]

Advances in digital technologies spur new business models

But, perhaps the most compelling development among solution providers is the emergence of new business models that aggregate customer-sited storage to provide a range of services to utilities, grid operators and electricity customers (residential and/or C&I). Aggregation, powered by artificial intelligence, blockchain, and predictive analytics, could provide greater flexibility for utilities and developers and greater choice for residential and C&I customers. The rise of the battery aggregators is upon us and this approach to deploying and integrating battery storage is demonstrating itself to be financially viable—even without widespread access to wholesale energy markets, since services can be sold directly to end customers or existing utilities.

Companies such as US-based Stem are focusing on offering storage as a service to the behind-the-meter C&I segment and to utilities and grid operators. Via a platform that uses artificial intelligence to dispatch and reconfigure a network of batteries at a moment's notice, Stem offers its C&I customers turn-key convenience and flexibility. They can better manage their energy decisions and avoid demand charges—all without manual intervention such as turning off heating, ventilation, and air conditioning systems and lights. On the flip side, Stem offers utilities and grid operators the ability to absorb or discharge energy from the system to balance the grid and offset capacity shortfalls.

Elsewhere, start-ups are focusing on behind-the-meter residential storage, but the same concepts apply: aggregating groups of batteries or solar-plus-storage systems to provide services to the grid or to participate in energy trading. Different types of aggregation models are currently being explored by several players in Europe and have the potential to make residential storage more viable. In the UK, local player Moixa offers a "GridShare" scheme where qualifying battery customers can sign up and get cash back in return for allowing the company to intelligently manage their batteries to help balance the grid. As explained on the company's web site, GridShare uses the "smart brain built into every Moixa battery to combine the stored energy (or spare capacity) of each customer." Participants are typically rewarded either via a fixed annual payment or a share of the overall revenue generated."[84]

The potential for aggregation grows tremendously as it intersects with expanding electric vehicle markets, since each electric vehicle contains a battery that could potentially be pooled with others to provide grid services. European transmission system operator, TenneT, which primarily serves Germany and the Netherlands, is exploring ways to integrate flexible capacity supplied by electric vehicles into the electric grid. In a pilot project in the Netherlands, renewable energy company, Vandebron, will work with customers who own electric vehicles to make the capacity of their car batteries available to help TenneT balance the grid.[85] This effort is seen as groundbreaking because of its novel use of blockchain technology to create a highly responsive, permissioned network. Often associated with direct trading platforms, blockchain typically functions as a virtual ledger. It records a continuously growing list of transactions, which are linked and

Hawaiian Electric Co. (HECO), in conjunction with Stem, has made inroads in the commercial and industrial solar-plus-storage market by piloting a 1 MW virtual aggregated power plant in Oahu.[89] The project provides intelligent storage as a service to 29 commercial customers, helping them to reduce their electricity demand charges as well as to better integrate and utilize their on-site generation.[90] Simultaneously, the virtual power plant allows HECO to draw upon the collection of batteries to help stabilize the grid and meet peak demand.[91]

secured simultaneously using cryptography.[86] However, in this instance, the blockchain tracks the availability of each car battery and records its action and contribution in response to the grid operator's signal. This allows the batteries to be tapped for only a few seconds at a time, thus providing precision response to grid variations without compromising customers' ability to charge their cars.[87] TenneT is also working with German residential battery provider, the sonnen Group, to pilot a similar blockchain-enabled network of residential solar batteries.[88]

Digital advances have also opened the door for electricity consumers to participate directly in the energy sector. Several companies are experimenting with blockchain-enabled peer-to-peer (P2P) trading platforms that facilitate the direct sharing of stored and/or self-generated electricity among home owners or businesses. Households participating in pilot projects as far flung as New York, Australia, Germany and Bangladesh can now trade small amounts of green electricity among themselves through blockchain platforms and microgrid management systems, many of which have storage components.[92] These developments collectively point to the potential advent of an energy "cloud" environment, where shared pools of energy can be accessed and traded on-demand, either with or without an intermediary.

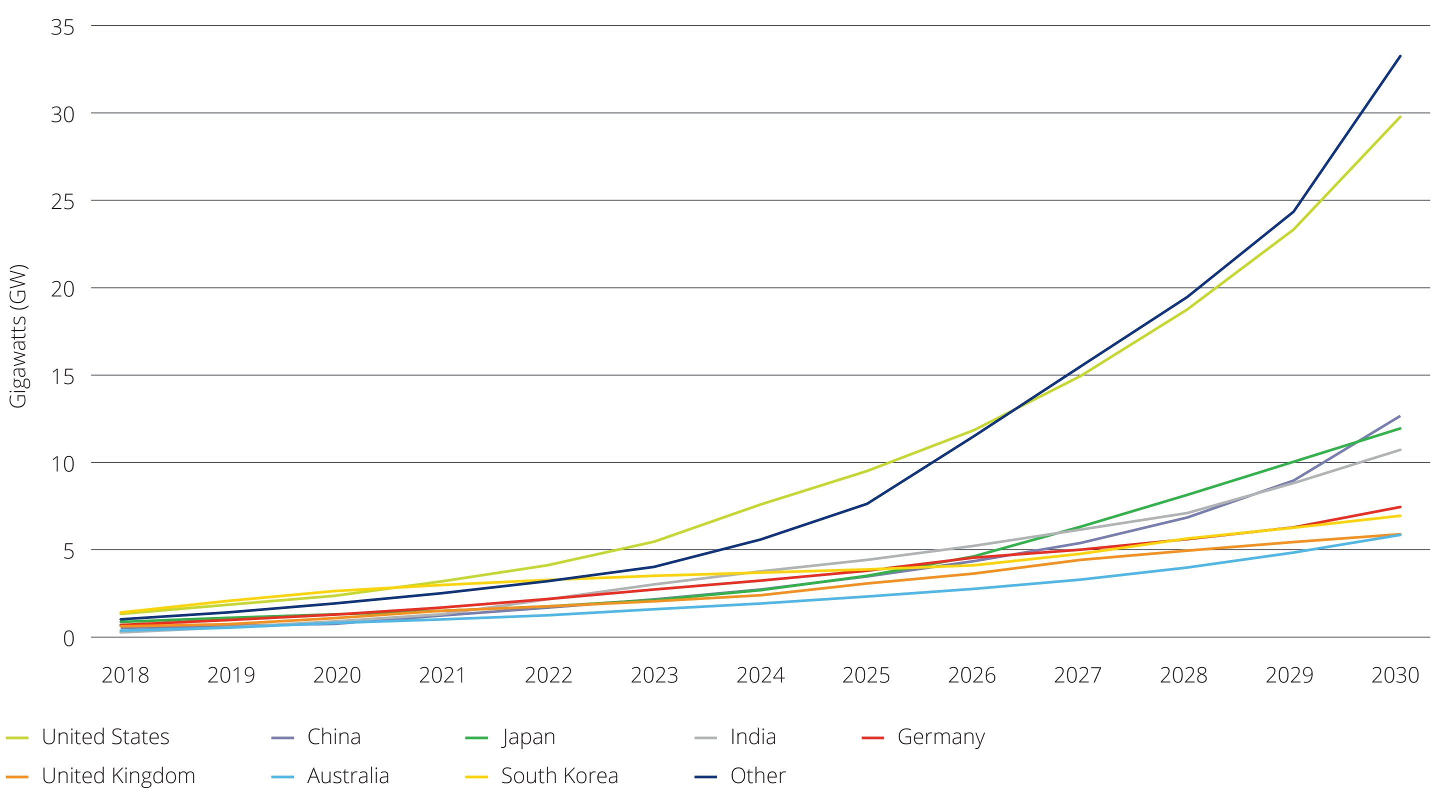
Conclusion

Only a few years ago, the concept of aggregating batteries to provide grid services or to facilitate peer-to-peer electricity trading seemed like science fiction. Leaps in adjacent digital technologies, such as artificial intelligence, predictive analytics and blockchain, are multiplying the uses and benefits of battery deployment. These mutually reinforcing mechanisms—not just improvements in battery performance and cost—are why the sector is so dynamic.

Also, though "storage" and "renewables" are often used in the same sentence, energy storage isn't just about integrating intermittent wind and solar output: battery solutions, which can be deployed rapidly and with pinpoint precision, can be used to make the overall grid more efficient and resilient, regardless of the generation sources. This makes the storage story all the more compelling.

For these reasons, battery storage is becoming supercharged around the world. In addition, battery prices are falling and storage markets are developing much faster than anticipated (see Figure 4). Storage solutions are already a focal point of national energy policy in nations that are establishing their energy systems, while they are being used to add flexibility and stability to the grid in countries with more mature energy sectors. To learn more about the progress and promise of battery storage as a global phenomenon, we invite you to explore the country-specific data and use cases featured throughout this paper.

Figure 4. Projected global cumulative storage deployment by country 2018-2030



Source: Bloomberg New Energy Finance

Endnotes

1 P&S Market Research, "Energy Storage Market to Reach $26,137 Million by 2022," Press Release, July 07, 2017, https://globenewswire.com/news-release/2017/07/07/1041306/0/en/Energy-Storage-Market-to-Reach-26-137-Million-by-2022-P-S-Market-Research.html, accessed October 6, 2017.

2 Peter Maloney, "Global energy storage market to hit 8.8 GW by 2025, IHS Markit says," *Utility Dive*, August 4, 2017, http://www.utilitydive.com/news/global-energy-storage-market-to-hit-88-gw-by-2025-ihs-markit-says/448606/, accessed October 6, 2017.

3 A "prosumer" is a consumer who produces electricity and feeds it back into the grid.

4 Brian Fung, "Tesla's enormous battery in Australia, just weeks old, is already responding to outages in 'record time,'" *The Washington Post*, December 26, 2017, https://www.washingtonpost.com/news/the-switch/wp/2017/12/26/teslas-enormous-battery-in-australia-just-weeks-old-is-already-responding-to-outages-in-record-time/?utm_term=.3cc730fed5da, accessed January 28, 2018.

5 Ibid.

6 Ibid.

7 Marlene Motyka and Andrew Slaughter, "Serious Business: Corporate procurement rivals policy in driving growth of renewable energy," Deloitte, 2017, https://www2.deloitte.com/us/en/pages/energy-and-resources/articles/corporate-procurement-driving-renewable-energy-growth.html.

8 Florida Power & Light Company, "FPL unveils first solar-plus-battery system in the US that can increase solar plant output," *PR Newswire*, February 9, 2018, https://www.prnewswire.com/news-releases/fpl-unveils-first-solar-plus-storage-system-in-the-us-that-can-increase-solar-power-plant-output-300596527.html, accessed February 15, 2018.

9 Ibid.

10 Ibid.

11 Florian Mayr, "Your guide to stationary energy storage in Europe Part 1: Germany," Apricum Group, November 14, 2016, https://www.apricum-group.com/guide-stationary-energy-storage-europe-part-1/, accessed December 13, 2017.

12 Mike Munsell, "German energy storage market to reach $1 billion by 2021," *GTM*, July 28, 2016, https://www.greentechmedia.com/articles/read/german-energy-storage-market-to-reach-1b-by-2021#gs.gi4rL1s, accessed December 13, 2017.

13 Mayr, "Your guide to stationary energy storage in Europe Part 1: Germany."

14 Munsell, "German energy storage market to reach $1 billion by 2021."

15 Jeff St. John, "NYISO's energy storage roadmap: A plan to match the state's new mandate," *GTM Squared*, December 8, 2017, https://www.greentechmedia.com/squared/read/nyiso-energy-storage-roadmap-a-plan-to-match-the-states-new-mandate#gs.ra91ong, accessed December 13, 2017.

16 Eric Wesoff, "FERC's Energy Storage Ruling Could Jump-start Big Batteries," *GTM*, August 12, 2013, https://www.greentechmedia.com/articles/read/fercs-energy-storage-ruling-could-jump-start-big-batteries#gs.JJ_Knso, accessed January 14, 2018.

17 Ibid.

18 Patrick Nixon, "Tech companies eyeing energy storage in Chile," *BN Americas*, August 29, 2017, https://www.bnamericas.com/en/news/ict/tech-companies-eyeing-energy-storage-ops-with-new-chile-regulation/, accessed December 16, 2017.

19 Emeliano Bellini, Italy opens ancillary services market to pilot renewable energy projects and storage projects, *PV Magazine*, May 9, 2017, https://www.pv-magazine.com/2017/05/09/italy-opens-ancillary-services-market-to-pilot-renewable-energy-and-storage-projects/, December 16, 2017.

20 Federal Energy Regulatory Commission, "FERC issues final rule on electric storage participation in regional markets," Docket Nos. RM16-23, News Release, February 15, 2018, https://www.ferc.gov/media/news-releases/2018/2018-1/02-15-18-E-1.asp#.WocN2hPwZuV.

21 "Chile: 70% of electricity to come from renewables by 2050," *Tidal Energy Today*, January 6, 2016, https://tidalenergytoday.com/2016/01/06/chile-70-of-electricity-to-come-from-renewables-by-2050/, accessed January 27, 2018.

22 Patrick Nixon, "Tech companies eyeing energy storage in Chile."

23 Ibid.

24 "Energy storage as key driver for the growing Italian PV market," *PV Europe*, May 16, 2017, http://www.pveurope.eu/News/Energy-Storage/Energy-storage-as-key-driver-for-the-growing-Italian-PV-market, accessed December 13, 2017.

25 Ashley Song, "South Korean government eyes energy storage systems," *Korea Bizwire*, July 6, 2017, http://koreabizwire.com/south-korean-government-eyes-energy-storage-systems/87773, accessed December 18, 2017.

26 Jason Deign, "Who will benefit from South Korea's solar-plus-storage incentive?" *GTM*, October 5, 2016, https://www.greentechmedia.com/articles/read/who-will-benefit-from-south-koreas-storage-incentive#gs.S==B4X0, accessed January 29, 2017.

27 Ibid.

28 Ibid.

29 Sam Pothecary, "South Korea to give incentives for energy storage as part of renewables spending spree," *PV Magazine*, September 20, 2016, https://www.pv-magazine.com/2016/09/20/south-korea-to-give-incentives-for-energy-storage-as-part-of-renewables-spending-spree_100026184/, accessed January 29, 2018.

30 Jonathon Gifford, "New installs and retrofits behind Australia's residential storage boom," *PV Magazine*, https://www.pv-magazine.com/2017/04/06/new-installs-and-retrofits-behind-australias-residential-storage-boom/, accessed January 15, 2018.

31 Mayr, "Your guide to stationary energy storage in Europe Part 1: Germany."

32 Florian Mayr, "Your guide to stationary energy storage in Europe Part 2: UK and Italy," *Apricum*, December 12, 2106, https://www.apricum-group.com/your-guide-to-stationary-energy-storage-in-europe-part-2-uk-and-italy/, accessed December 13, 2017.

33 Robert Walton, "Honolulu storage permits surge 1700% in one year, new report says," *Utility Dive*, February 5, 2018, https://www.utilitydive.com/news/honolulu-storage-permits-surge-1700-in-one-year-new-report-says/516331/, accessed February 10, 2018.

34 Ibid.

35 Mayr, "Your guide to stationary energy storage in Europe Part 1: Germany."

36 Mayr, "Your guide to stationary energy storage in Europe Part 2: UK and Italy."

37 Rebecca Armitage and Amy Bainbridge, "Solar batteries exploding in popularity with uptake tipped to triple in 2017, audit finds," *ABC*, February 13, 2017, http://www.abc.net.au/news/2017-02-14/solar-batteries-like-tesla-exploding-in-popularity/8259830, accessed December 13, 2017.

38 Ibid.

39 Jonathon Gifford, "New installs and retrofits behind Australia's residential storage boom," *PV Magazine*, https://www.pv-magazine.com/2017/04/06/new-installs-and-retrofits-behind-australias-residential-storage-boom/, accessed January 15, 2018.

40 Ibid.

41 Ibid.

42 Armitage and Bainbridge, "Solar batteries exploding in popularity with uptake tipped to triple, audit finds."

43 National Portal of India, "Smart cities mission," https://www.india.gov.in/spotlight/smart-cities-mission-step-towards-smart-india, accessed January 26, 2018.

44 Ibid.

45 Jackie Wattles, "India to sell only electric cars by 2030," *CNN Tech*, June 30, 2017, http://money.cnn.com/2017/06/03/technology/future/india-electric-cars/index.html, accessed January 26, 2017.

46 Mike Stone, "India's first grid-scale battery project signals coming boom for energy storage," *GTM*, January 27, 2017, https://www.greentechmedia.com/articles/read/indias-first-grid-scale-battery-project-signals-a-coming-boom-for-storage#gs.FKR1lsw, accessed January 26, 2017.

47 Ibid.

48 Max Berre, "The energy storage landscape in Japan," EU-Japan Economic Centre for Cooperation, September 2016, https://www.eubusinessinjapan.eu/sites/default/files/energy_storage_landscape_in_japan.pdf, pg. 7

49 Ibid.

50 Mike Stone, "Japanese utilities invest in big batteries to help bring more renewables on-line," *GTM*, May 19, 2015, https://www.greentechmedia.com/articles/read/japanese-utilities-invest-in-big-batteries#gs.1zMMgDk, accessed January 26, 2018.

51 Andy Colthort, "Japan hopes 'world's biggest' battery test facility will play a crucial role in standards," *Energy Storage News*, March 3, 2016, https://www.energy-storage.news/news/japan-hopes-worlds-biggest-test-facility-for-batteries-will-play-crucial-ro, accessed January 26, 2018.

52 Stone, "Japanese utilities invest in big batteries to help bring more renewables on-line."

53 Mark Chediak, "California energy storage companies wade into Japan market," *Bloomberg Technology*, December 11, 2017, https://www.bloomberg.com/news/articles/2017-12-11/california-battery-startup-goes-global-with-storage-in-japan, accessed January 26, 2018.

54 Ibid.

55 Ibid.

56 Ibid.

57 Jason Deign, "Xcel attracts 'unprecedented' low prices for solar and wind paired with storage," *GTM*, January 8, 2018, https://www.greentechmedia.com/articles/read/record-low-solar-plus-storage-price-in-xcel-solicitation#gs.dcuQe1w, accessed February 15, 2018.

58 Ibid.

59 Scott Moskowitz, "Trends shaping the energy storage inverter market: Falling prices, fragmentation, new features," *GTM*, September 12, 2017, https://www.greentechmedia.com/articles/read/trends-shaping-the-energy-storage-inverter-market#gs.s6xsLak, accessed December 15, 2017.

60 Edison Electric Institute (EEI), "Harnessing the Potential of Energy Storage," April 2017, http://www.eei.org/issuesandpolicy/generation/Documents/EEI_HarnessingStorage_Final.pdf, accessed December 16, 2017.

61 "Comments of Jason Burwen, policy and advocacy director of the Energy Storage Association before the Federal Energy Regulatory Commission," November 19, 2015, accessed February 16, 2018, energystorage.org/system/files/attachments/ferc_statement_v3.1.docx

62 Mayr, "Your guide to stationary energy storage in Europe Part 2: UK and Italy."

63 Ibid.

64 Heidi Bishop, Ryan Hledik, Roger Lueken, and Colin McIntyre, "Stacked Benefits: Comprehensively Valuing Battery Storage in California," *The Brattle Group*, September 2017, http://files.brattle.com/files/7208_stacked_benefits_-_final_report.pdf.

65 Ibid.

66 Peter Maloney, "Brattle: Regulatory barriers prevent stacking of battery benefits, *Utility Dive*," September 13, 2017, https://www.utilitydive.com/news/brattle-regulatory-barriers-prevent-stacking-of-battery-benefits/504773/, accessed December 17, 2017.

67 "California regulators first to allow multiple revenue streams for energy storage," *Utility Dive*, February 13, 2018, https://www.utilitydive.com/news/california-regulators-first-to-allow-multiple-revenue-streams-for-energy-st/516927/, accessed February 15, 2018.

68 Andrew Berger, "California ramps up energy storage plans with enactment of four new bills," *Renewable Energy World*, September 26, 2016, http://www.renewableenergyworld.com/articles/2016/09/california-ramps-up-energy-storage-plans-with-enactment-of-four-new-bills.html, accessed February 10, 2018.

69 Ibid.

70 Peter Maloney, "New York energy storage target official after Gov. Cuomo signs bill," *Utility Dive*, December 1, 2017, https://www.utilitydive.com/news/new-york-energy-storage-target-official-after-gov-cuomo-signs-bill/512056/, accessed December 15, 2017.

71 Andy Colthorpe, "NV Energy to consider energy storage in 330MW renewables push," *PV Tech*, January 10, 2018, https://www.pv-tech.org/news/nv-energy-to-consider-energy-storage-in-330mw-renewables-push , accessed February 2018.

72 Robert Walton, "Maryland is first state to launch energy storage tax credit," *Utility Dive*, February 13, 2018, https://www.utilitydive.com/news/maryland-is-first-state-to-launch-energy-storage-tax-credit/517011/, accessed February 2018.

73 Herman K. Trabish, "As feds focus on baseload, grid modernization is sweeping the nation," *Utility Dive*, November 14, 2017, https://www.utilitydive.com/news/as-feds-focus-on-baseload-grid-modernization-is-sweeping-the-nation/510680/, accessed December 16, 2017.

74 Julia Pyper, "California passes huge energy storage mandate," *GTM*, October 17, 2013, https://www.greentechmedia.com/articles/read/california-passes-huge-grid-energy-storage-mandate#gs.5wu2Okk, accessed January 28, 2018.

75 Julia Pyper, "Tesla, Greensmith, AES deploy Aliso Canyon storage in record time," *GTM*, January 2, 2017, https://www.greentechmedia.com/articles/read/aliso-canyon-emergency-batteries-officially-up-and-running-from-tesla-green#gs.g4TFID4, accessed January 28, 2018.

76 Peter Maloney, "CAISO proposes load-shifting product for energy storage," September 25, 2017, Utility *Dive*, https://www.utilitydive.com/news/caiso-proposes-load-shifting-product-for-energy-storage/505665/, accessed December 18, 2017.

77 Robert Walton, "3 California Natural Gas Plants, could be replaced with energy storage," *Utility Dive*, December 14, 2017, https://www.utilitydive.com/news/3-california-gas-plants-could-be-replaced-with-energy-storage/513033/, accessed December 16, 2017

78 Emma Foehringer Merchant, "Have we reached peak peaker? 'I can't see why we should build a gas peaker after 2025," *GTM*, December 12, 2107, https://www.greentechmedia.com/articles/read/battery-storage-is-threatening-natural-gas-peaker-plants#gs.tQG3r0I, accessed February 11, 2018.

79 Julian Spector, "Years In, NY REV lacks major storage action. Has to change soon," *GTM*, September 28, 2017, https://www.greentechmedia.com/articles/read/new-york-rev-still-lacks-major-storage-action-that-may-have-to-change#gs.EQpgPWo, accessed December 16, 2017.

80 Gavin Bade, "APS to deploy 8 MWh of battery storage to defer transmission investment," *Utility Dive*, August 9, 2017, https://www.utilitydive.com/news/aps-to-deploy-8-mwh-of-battery-storage-to-defer-transmission-investment/448965/, February 10, 2018.

81 Ibid.

82 Alex Eller, "Energy storage will disrupt transmission and distribution investments," *Utility Dive*, October 17, 2017, https://www.utilitydive.com/news/energy-storage-will-disrupt-transmission-and-distribution-investments/506945/, accessed January 26, 2017.

83 Ibid.

84 Mayr, "Your guide to stationary energy storage in Europe Part 2: UK and Italy."

85 TenneT, Organization Info., https://www.tennet.eu/news/detail/tennet-unlocks-distributed-flexibility-via-blockchain/, accessed January 28, 2018.

86 Wikipedia, "Blockchain," https://en.wikipedia.org/wiki/Blockchain, accessed January 28, 2018.

87 TeneT, Organization Info., "Europe's first blockchain project to stabilize the power grid launches: TenneT and sonnen expect results in 2018," November 2, 2017, https://www.tennet.eu/news/detail/europes-first-blockchain-project-to-stabilize-the-power-grid-launches-tennet-and-sonnen-expect-res/, accessed December 17, 2017.

88 Ibid.

89 Andy Colthorpe, "Stem connects 1 MW aggregated virtual power plant in Hawaii," *Energy Storage News*, January 23, 2017, https://www.energy-storage.news/news/stem-connects-1mw-aggregated-virtual-power-plant-in-hawaii, accessed January 27, 2018.

90 Ibid.

91 Ibid.

92 Diane Cardwell, "Solar experiment lets neighbors trade among themselves," *New York Times*, March 13, 2017, https://www.nytimes.com/2017/03/13/business/energy-environment/brooklyn-solar-grid-energy-trading.html, accessed December 17, 2017.

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