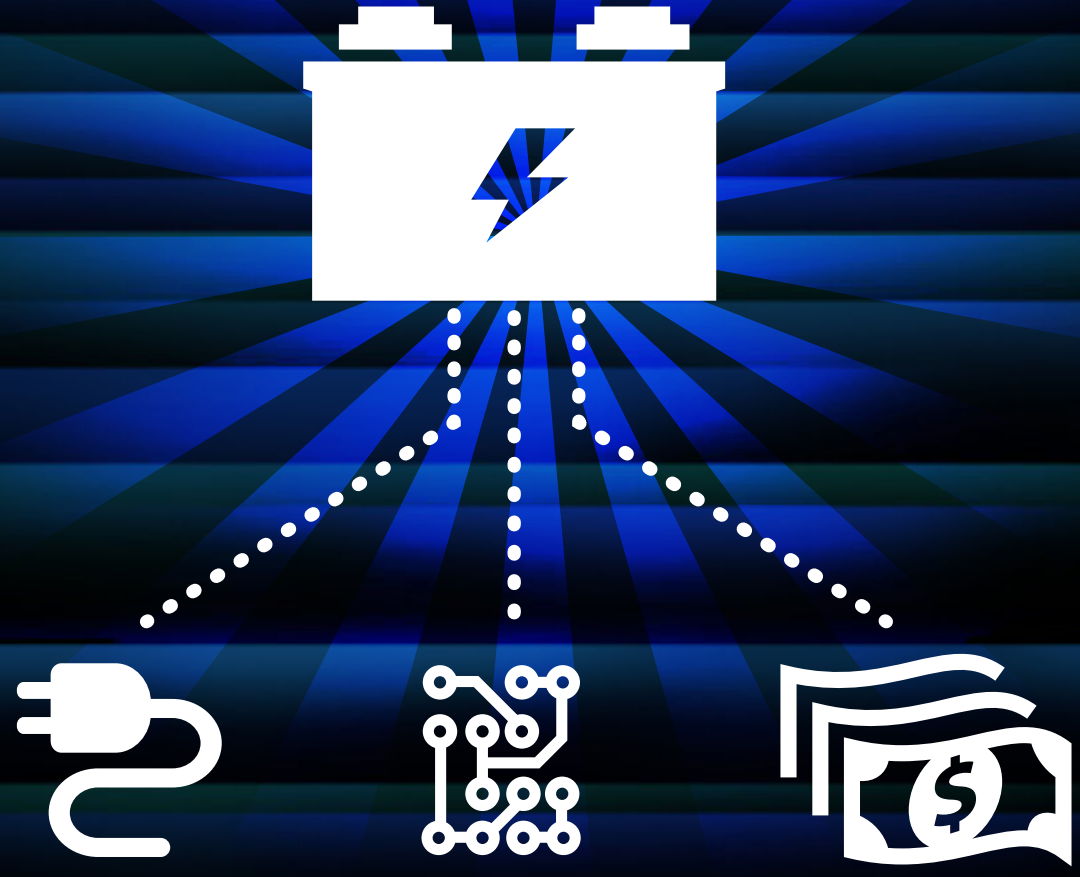
A FROST & SULLIVAN WHITE PAPER

Energy Storage

Driving Progress and Advancement in Power, Technology, and the Economy



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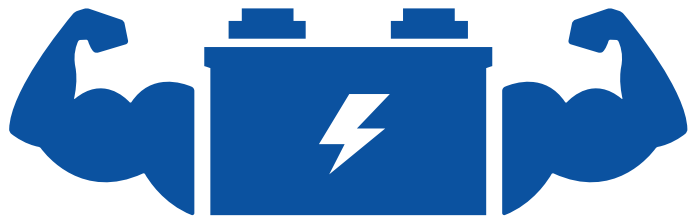
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Energy Needs are Increasing

The energy world has seen rapid and revolutionary changes in technology and business models, and this pace of change is expected to accelerate in the coming years. Electricity demand will grow as the economy expands, infrastructure spending increases, and everyday life becomes more energy-intensive. Renewable power is becoming a larger portion of the power portfolio, and the grid is irreversibly transitioning from a center point of power generation radiating out across a distribution system, to one that is increasingly fragmented and incorporates numerous points of generation and usage. Improvements in efficiency of power generation, transmission, and usage will help adjust for some of the increase, however the net effect will still be a need for more, and higher quality, electricity through at least 2040.

More power will be needed beyond the meter



The Connected World

The future of energy therefore necessitates both growth and flexibility. The Internet of Things (IoT) also means more power will be needed beyond the meter, and across equipment and infrastructure, in the vehicle, and on the person. The increasing number of devices and equipment that are linked and communicating means high power quality will also be required across telecommunication systems that transfer data, the data center that store and translate information, and the businesses and people that utilize the data's implications. All these challenges—and opportunities—require energy storage.

The future of energy storage is one that will drive safe, clean, and affordable power:

- It will balance power supply and demand to alleviate strain on the grid and mitigate costly energy sector investments.
- It will support the collection, transfer, storage and usage of data that daily life and industry demands.
- And it will enable revolutionary business models across energy, industry and infrastructure.

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Energy Storage Drives Progress

Many of the innovative changes across industry, power, and even everyday life will all depend, whether direct or indirect, on energy storage. Whether powering a smart watch or stabilizing a smart grid, backing up a major enterprise data center or a small rooftop solar panel, energy storage (ES) affects all facets of modernity and its importance in the years to come cannot be overemphasized.

Rechargeable Energy Storage is in Demand

Energy demand is growing both at an absolute level as well as by person and per company. While technology is becoming more energy efficient—our cell phones, laptops, and services have considerably more computing power without the same proportional increase in energy usage, the net effect is still one of rising power demand. Datacenters for example are one of the largest and fastest growing users of both power and power storage. While the number of data centers in the US continues to rise, their power usage increase as well. A typical tier 3 data center's power per rack will not be less than 3kW, and are usually closer to 4.5kW with peak power up to 15kW for high-performance computing needs. Increased domestic manufacturing and construction, particularly for infrastructure, in the coming years is another major driver pushing power demand. Energy storage will help fill the demand by shifting power from when it's cheapest to produce to when it's most in demand. The global market for rechargeable energy storage is already at about $60 billion globally, according Frost & Sullivan research, and has an astounding 10% compound annual growth rate (CAGR) anticipated from 2016 through at least 2020.

All Markets Need Energy Storage...

...But Some Need it More

At the end of the day, all aspects of the US economy will be affected by energy storage, though some more directly than others. Along with data centers, other growth markets identified by Frost & Sullivan's research include many aspects of industry, the automotive sector, thanks to hybrid-electric and electric vehicles.
In the power sector, Battery Energy Storage Systems (BESS) typically used in renewable energy and power grid applications, which will be some of the principle applications for ES in the coming years. A BESS system usually combines batteries with inverters and power stability and peak load control, and hence facilitate easier integration of ES into a power and grid system. Grid connected solutions will be driven by the need for better power quality and smoothing out peak power loads.

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Consumer and residential applications are also growing very rapidly, particularly in the mid- to long-term thanks to smarter homes, communities, and our transition to more “connected living.”

Industrial Applications

All industrial verticals are restrained by the current technical limits of energy storage, and can expand in growth and profitability as the market advances. Energy storage improves the power quality and reduces electricity costs for a manufacturing plant. Batteries and other formats for energy storage keep smart devices, whether on an assembly line or an oil rig, connected and delivering critical data. Frost & Sullivan research indicates that lithium-ion batteries, for example, will be driven largely by industrial verticals such as telecommunications, the afore mentioned data centers, medical devices, aerospace and defense, and industrial equipment manufacturing and usage.

Consumer

The number of electronic devices used by consumers is staggering. Frost & Sullivan data shows that in 2015 alone, nearly 280 million smart phones were delivered. This does not include tablets, laptops, smart watches, and fitness trackers, and the increasing volume of web-connected everyday items such as thermostats, home entertainment, cameras, and even toothbrushes. An aging population will likely further add to the list with more health and wellness technologies to allow for more aging-in-place. This impacts the energy storage market directly, in terms of batteries needed to power these devices. It also has an impact on the amount of power consumed per capita, not only for charging these devices but also for transmitting and processing the data from these devices.

In 2015, nearly
280 million
smart phones
were delivered
to consumers



Although considered an established market, the market for lithium-ion batteries to this industry will continue to experience double-digit growth directly to the

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confluence of smart devices and more connected living, not including the related growth to utility and telecom energy and energy storage.

Cities and Governments

One way to look at the expanding use of energy storage across infrastructure is by system—that is, energy storage needed for the power grid, for traffic signals and street lights, or across security and monitoring of municipal water systems. However the convergence of these systems, and "smart" systems in particular, also manifests as markets where the overall city or government is the customer. Smart cities will be a significant opportunity for energy storage. Modern, well run cities will not only have independent services that are digitalized and well connected, but truly *smart* cities will have these services and departments leveraging each other. For example, healthcare, traffic, and emergency services will come together to reduce air pollution, reduce accidents, and allow first responders quicker response times. Cities will need to ensure these systems work and are secure, both in terms of physical security and cybersecurity. A city cannot have security, much less efficiency and overall wellness, without the power quality to keep systems up and running at all times, and energy storage is the only way to ensure this.

Energy storage is the only way to ensure government systems are kept up and running at all times



Automotive

Innovations and growth of both electric and hybrid-electric vehicles have helped advance the development of the ES market. It's also brought the limitations of the cost, weight, and run time of current energy storage technologies to light. These markets will continue to grow, and will also contribute to ES growth in related markets, such as the power grid industry needing to account for more EVs being plugged in, and as vehicle-related telemetrics and infotainment add to the glut of information streaming across telecom networks and through data centers.

Utilities

Arguably the most significant need for energy storage is, understandably, across the broader energy infrastructure itself. The top revenue driver in battery storage

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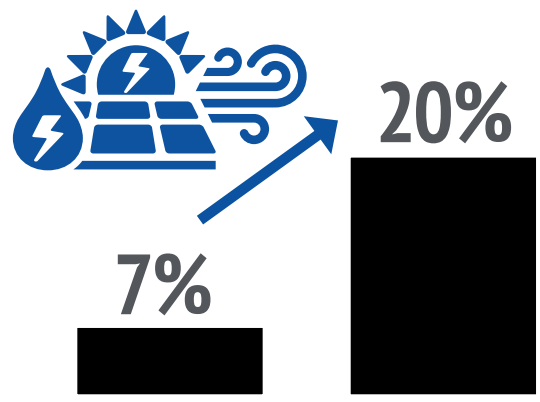
systems, at least in the short term, is the utility industry and it's need to cope with a rapidly evolving power ecosystem. BESS systems are revolutionizing the industry thanks to the game changing nature of the technology to balance power supply and demand instantaneously—*within milliseconds*—which makes power networks more resilient, efficient, and cleaner than ever before.

Energy storage is needed at utility and large-scale industrial power applications for three main reasons:

- **Balance the load:** Shift energy consumption into the future, often by several hours, so that more existing generating capacity is used efficiently
- **Bridge power:** Ensuring there is no break in service during the seconds-to-minutes required to switch from one power generation source to another, which can be needed during emergency power situations and unplanned outages
- **Power quality management:** Controlling of voltage and frequency to avoid damaging sensitive equipment, an increasing concern that storage can alleviate whenever needed, for a few seconds or less, many times each day.

Energy storage systems also have the advantage of being "fuel neutral." As the US economy grows we need significantly more power from all sources. But whether that source is renewable, fossil or nuclear, energy storage can capture excess electricity at high efficiencies for optimal use during outages, peak hours, or whenever effective grid management is a challenge. Because ES can help a system store power and reuse it during peak times, they carry a positive influence on reducing carbon footprint regardless of the original power generating sources.

By 2035, non-hydro renewable energy will account for 20% of nameplate installed power in the US, up from only 7% in 2016



Support from government incentives, expected increases in overall infrastructure spending, and continued piloting of utility scale energy storage projects shows that energy storage is a key priority for utilities. However the most compelling driver for recent growth in utility energy storage has been the rapid expansion of renewable power installations and integration into the power grid. From utility scale wind

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farms to small rooftop photovoltaic (PV) systems, renewable energy is one of the fastest growing power generation technologies in the US—by 2035, non-hydro renewable energy will account for 20% of nameplate installed power in the US, up from only 7% in 2016. In California alone, by the end of 2016 the state had an estimated 5 GW of installed rooftop PV, enough to power over 3.6 million homes, and well exceeding the state's goal of 3 GW by 2017.

Renewable energy is attractive due to its carbon- and fuel-free operation and distributed nature; that is, in many cases it can be installed at or near the source of energy usage, thereby reducing transmission and distribution costs and complexity. The cost of renewable energy has also been falling, both in terms of the equipment itself as well as new business models that help mitigate initial capital expenditures. However, from a technical standpoint for the utilities and power grid operators, renewable energy can add cost and cause complications. Solar and wind produce energy intermittently—only generating power when the sun shines or when the wind blows. This on-and-off flow of electricity can be damaging to equipment and dangerous to operations personnel. Peak generation times can be unpredictable due to variations in weather patterns, and often will not align with times of peak usage. Energy storage can resolve these issues by collecting power whenever it is generated, and releasing it in a steadier, and safer, stream of electrons, preferably when prices are high and thereby also improving the system's economics.

Longer term, electric vehicles may also have a power usage and power quality impact on the grid. A few EVs in a neighborhood may not make much difference, but plugging in a couple million cars, especially at peak times such as after the evening commute home, will unbalance the power grid. Storing energy when these systems are not in use and releasing it, either close to the charging station or along the overall grid, will help improve power safety, quality, and cost, and if generated by renewable sources will also reduce the environmental footprint.

Energy storage can help **mitigate the costs** of expanding the power grid to keep up with demand



Utilities, states, and federal governments are installing and incentivizing energy storage at an encouraging rate in order to help mitigate the costs of expanding the power grid to keep up with demand. For example, California's AB2514 mandate uses

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energy storage to protect the grid, reduces upgrades to the grid, and provides more capacity to balance the decommissioning of nuclear assets. Southern California Edison (SCE) is using energy storage in trials with customers who currently have solar power rooftops. SCE wants to drive an energy storage market at customer sites to help balance the load at the source, rather than only at the grid. In Germany, which has a healthy installed market of over 1 million solar homes thanks to years of incentives through feed-in tariffs, independent power producer Lichtblick is using energy storage to create a virtual power plant—or "swarm"—of distributed solar panels, which will also incorporate home heating and EV chargers.

Drivers of Energy Storage

Technology Will Drive ES in the Short Term

Renewable power and EVs are discussed above in the context of a traditional power grid with a main source of electricity—a power plant—and homes and buildings as users of that electricity, being disrupted by additional generation and consumption along the grid. This increasing fragmentation of the traditional system is also bringing in new business models for the sale and usage of power, which not only adds opportunities but also adds complexity to the overall ecosystem. For example, the opportunity for microgrids is rising dramatically thanks to falling prices of renewables, improved energy storage technology, and much better monitoring and controls.

Microgrid

Microgrids, as the name indicates, are smaller, self-sufficient power grids, which may or may not be integrated into a larger utility grid. However, a microgrid is not generally configured the same as a traditional spoke-and-wheel power grid. Microgrids typically employ several sources of power generation, many or all of them renewable-based, and hence require energy storage to mitigate the same intermittent and off-peak generation challenges that face larger utility-scale grids. For example, a military base with solar power, fuel cells, battery-based energy storage, and diesel back-up generators that produce power for the installation could be considered a microgrid. Military bases were some of the first entities to adopt microgrids, but the configuration can also be seen at remote mining and oil & gas operations, large industrial centers, neighborhoods, and even hospitals and universities.

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Virtual Power Plant

Related to the microgrid is the virtual power plant (VPP), which has similarities to the microgrid concept from a generation standpoint but not necessarily from the user standpoint. A VPP is a collection of discrete but connected sources of power generation that can be managed in the aggregate, as one entity in terms of power buying and selling.

Solar PV rooftops are well suited for a VPP system, since by itself one small rooftop system may not match well with the energy needs of one building. However, combined with an energy storage system, multiple PV rooftops can be linked together to provide more power across the grid. A VPP system being tested in Germany is a PV-based system. A VPP could also have energy storage equipment along the grid to provide additional peak power. Energy storage gives a VPP the flexibility it needs to operate as a large, but highly nimble, "power plant."

Due to the distributed nature of these generating assets, each still needs to be monitored and controlled independently. A true VPP is a highly sophisticated entity, and can manage two-way power resources, price bidding, scheduling, even predicting usage patterns using artificial intelligence and weather data. A VPP can amass numerous distributed sources of generation in a diversified and balanced load portfolio and then play on the market, if regulations permit, as if it were a single power plant. However it is more complex than a microgrid in that VPPs rely on a sophisticated and extensive program encompassing asset owners, power users, grid operators, utilities, and regulators, whereas a microgrid can be set up independently, with the generator and user even being the same entity.

Revolutionary Business Models Will Drive ES in the Long Term

Energy storage has a clear technical advantage for grid and utility operations, such as for renewable power. It also enables new configurations such as microgrids and VPPs, which are not only technical advances but business models as well. As the power industry as we know it becomes increasingly fragmented, utilities will need to evolve their own business models to keep pace, and to keep from becoming relics of an older era.

For example, a rooftop PV system on a building can be owned and operated by the building owner, with the necessarily safety controls and permission from the local utility to integrate into the larger grid system. However, this PV system could also be owned and operated by the utility, thereby taking on the cost for equipment,

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installation, operation and maintenance, and then the resulting power (along with any supplied by the grid) is sold to the building owner. Or, a third party can play this role, and can combine these generating assets with others across the region and in essence be a virtual power plant and/or substitute utility. Loosely categorized as "energy-as-a-service," in either the utility or third party scenario, the building owner no longer carries the burden of buying equipment, warranties, maintenance time, and so forth. Instead, the building owner is buying green energy regardless of where it's generated or who owns the generating assets and, in this scenario, the generation happens to be at the usage site.

This is an entry point for new business models that do not need to stop at the meter. Energy-as-a-service may itself evolve, for example, to comfort-as-a-service: In this case, the building owner is not even buying electricity to power lighting fixtures, or a heating, ventilation, and air conditioning (HVAC) system, but rather is buying the right temperature, humidity, and lighting needed for the operations housed in the building. How much a utility or third party wants to embroil itself in the inner workings of the homes and businesses across the grid is a matter for their business models, and regulators, to decide. But none of this could take place at a significant scale without energy storage to allow on-site renewables, provide high power quality with back-up grid power, and ensure all the communication and control of the systems that make the solution work are powered and consistently on line.

Energy Storage and Utility Operations

Forever Intertwined

Due to the radical new changes across power technologies and business models, utilities will forevermore be dependent on energy storage. To summarize the various points of connectivity between energy storage and utilities:

- BESS is a key solution used for power generation and utility grid stability
- Large scale energy storage, both centralized and distributed, can provide load balancing, such as generators, gas turbines, and pumped hydro systems currently do on along the grid
- Large enough installations can also sell energy in massive volumes as a VPP, acting like an independent power producer
- Energy storage can reduce cost of infrastructure upgrades at both grid and central plant levels

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- Drivers for the utility include better control/management/oversight of energy assets that are already on the grid, better grid balancing, reducing expensive system expansion
- Drivers for customers include more use out of their ES investment, more control and lowering of electricity prices, better power quality, and a “greener” aspect to their businesses
- Drivers for others in the industry include creating and delivering new value propositions and business models.
- All these systems are again leading to new business models: Energy as a service, microgrids and virtual power plants for example

Batteries, Batteries, Batteries

In terms of the key technological advances for energy storage, systems come in many different configurations. Flywheels and ultracapacitors can be used, especially for short-term power discharge, but batteries are by far the most common energy storage technology.

Lithium Ion

Lithium ion batteries are at an exciting stage in the market, rapidly growing against lead acid, which dominated the market for many years and is still the main technology in automotive applications. Lithium ion chemistry is also showing more growth and promise than even some of the new technologies.

Lead Acid Technology

Lead acid technology was developed more than 150 years ago, and is still in use today for key applications. Their market revenues are estimated by Frost & Sullivan to have been roughly $29 Billion in 2016, and growing at a 3.4% CAGR from 2016 through 2020. Despite a healthy growth rate, it is threatened by the cost and technical advantages of lithium ion batteries, which have been the focus of energy storage in its quest for lower cost, higher reliability, and longer running solutions.

Nickel Batteries

Nickel batteries are about a $3 Billion market in 2016, with a CAGR of 3% through 2020. However, both nickel cadmium and nickel metal hydride, the long-time standard for consumer electronics, are in decline as the markets transition toward lithium ion.

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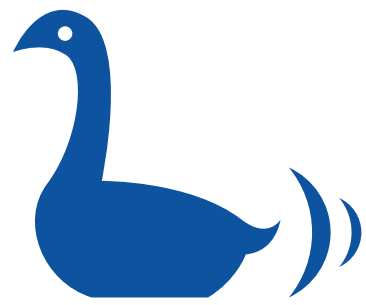
Flow Batteries and Solid-State Batteries

Flow batteries and solid-state batteries are another interesting technology in the works, though while there have been some pilot demonstration for flow batteries, both are years away from heavy commercialization and it's uncertain either would become a threat to lithium ion. Considering the vast and growing need for energy storage, even if the technology gains hold in some markets it is likely that the market will continue to leverage lithium ion's technical and cost benefits across applications.

Application-Specific Batteries

More application-specific batteries are also being researched, especially for consumer and medical device markets. In the future, energy storage may be foldable or waterproof; it may be the size of a grain of rice, power micro-sensors that could flow along a wastewater system or through a human body; it could be manufactured by a 3D printer on site or even possibly "sprayed on" for powering medical devices. All these applications are some distance in the future, but the amount of research across the application spectrum is testament to the growing need and recognition of energy storage.

The golden goose of the industry will be to create a battery that is cheap and lasts



Because of this expanding opportunity, the energy storage market is an attractive market for technical development and investors alike, and has continued prospects for strong growth. Research and development is trying to improve energy storage on all fronts, and in particular battery energy storage. The golden goose of the industry will be to create a battery that is cheap and lasts, and as such research has focused across different factors including reliability, quality, safety, life cycle, scalability, and price.

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The Future of Energy Storage Technologies, Today

Battery energy storage systems, which bundle batteries with inverters and controls, are a leading example of how energy storage is both a response to, and a driver for, massive market changes. Renewable energy requires energy storage to be safe, reliable and cost effective, and hence has helped grow the demand for advanced energy storage solutions. BESS have progressed so rapidly that they are, in turn, enabling new market solutions such as microgrids and virtual power plants.

Advanced Battery Energy Storage Systems

The US already has examples of advanced BESS applications participating in frequency regulation markets. PJM, the largest US regional transmission organization (RTO), also leads the market for energy storage for utility operations. In just over 10 years, PJM has added 300MW of energy storage, with more additions in the pipeline. One such pivotal installation is in the suburbs of Cincinnati, Ohio, owned by Willey Battery Utility and provided by Toshiba Corp. Toshiba's system is the Lithium battery based SCiB™ BESS, with a nameplate size 6MW and 2 MWh of operation. Toshiba's SCiB™ addresses the fluctuations in grid frequency caused by gaps between power being supplied to the grid versus current demand. This helps to better manage renewable power that feeds into the grid—and even reduces the amount of additional generation that is sometimes needed to balance intermittent renewable power. The system has been in operation since January of 2016 and is a textbook example of how transmission system operators can leverage the benefits of BESS for operating a grid that is more efficient, safer, greener, and less costly.

A year earlier, and also in PJM's Ohio territory, Toshiba partnered with Duke Energy, one of the US' most progressive utilities, on a 2MW/0.8MWh SCiB™ BESS. Toshiba has several other frequency regulation market installations, both current and in process, across the US.

Toshiba's SCiB™ technology is an excellent solution for providing frequency regulation, which addresses the fluctuations in grid frequency. The company also provided electric vehicle charging stations and plans to provide solutions for wind power, microgrids, and community power. The company also provides commercial and residential applications in the Japanese market. Toshiba has taken a noteworthy approach to the market: They have created a value proposition across the industry-lauded Lithium Ion technology, enhanced it with proprietary alternator and control

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technology, then scaled both the size and functions to apply across the ES spectrum. This means the company can deploy innovative, customized and economical BESS solutions globally to address the rapidly expanding and undeniably complex needs of the power industry.

The Road Forward

Demand for Power will Grow

Progress will demand more computing power, countries are perpetually expanding and upgrading their infrastructure, and markets are constantly searching for new avenues for growth. Economic advancement propels the demand for energy and strains existing power generation and transmission systems. Entities such as PJM and others around the world are seeing the clear benefits of energy storage to enable more efficient use of current generation and transmission assets, as well as the only way to integrate renewable power efficiently and effectively. For markets and economies to succeed and thrive, they require high quality, clean and affordable energy, and energy storage will continue to be one of the most fundamental, and fastest growing, solutions to enable technical innovation and drive economic prosperity.

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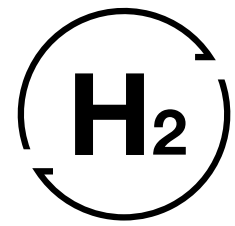
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Energy in America



Hydropower



Hydrogen Energy

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