# 2016 Top Markets Report Smart Grid Sector Snapshot

## Energy Storage

**State of the Market**

Improved technology has made storage solutions more efficient, offering both buyers and investors a stronger economic case for investment. Global policymakers are directing funds to storage research and offering subsidies, rebates and other tax incentives. The power industry is increasingly accepting of the fact that storage can play a part in the modern grid, though there may still be questions on how it should be incorporated and regulated. The result is that energy storage is closer to global commercial viability than ever before. In the first three-quarters of 2015, over 1.1 GW of new energy storage projects were announced globally.

The United States is at the forefront of storage technology and market development. Improvements in batteries, in particular, are bringing costs down across the board, leading to increased export opportunities for U.S. firms. According to BCC Research, the global market for grid-scale battery storage technologies is projected to reach nearly $4.0 billion in 2025, up from $716 million in 2015.

ITA anticipates that much of the near-term battery and non-battery storage deployment will be used for frequency regulation.

Finding additional revenue streams and deployment opportunities, however, will be integral to the scale-up of energy storage technologies. Other drivers for energy storage technology deployment include:

- Maintenance deferrals of transmission and distribution investments and upgrades
- Integration of intermittent renewable energy resources

A number of U.S. firms have commercialized products in this sub-sector. American businesses are well-positioned to deliver battery, compressed air and other storage solutions to countries that are implementing more renewable resources in their grid.

**Technologies[1] and Capabilities**

ITA considers mechanical and electrochemical storage options, such as batteries, as the most commercially promising. These technologies are at varying stages of development, with some at or near maturity while others are still in relatively early stages.

- **Pumped Hydro:** Pumped hydro employs off-peak electricity to pump water from a reservoir up to another reservoir at a higher elevation. When electricity is needed, water is released from the upper reservoir through a hydroelectric turbine into the lower reservoir to generate electricity. This technology has the highest capacity of all the storage technologies assessed because its size is limited only by the size of the available upper and lower reservoirs. Environmental concerns over water and land use, however, have emerged in recent decades. In the United States, the earliest plant was built in the late 1920s, and the last pumped storage plant was commissioned in the 1980s.

- **Compressed Air Energy Storage (CAES):** CAES systems use off-peak electricity to compress and store air in reservoirs, which are either underground caverns or aboveground pipes or vessels. When electricity is needed, the compressed air is heated, expanded, and directed through an expander or conventional turbine-generator to produce electricity.



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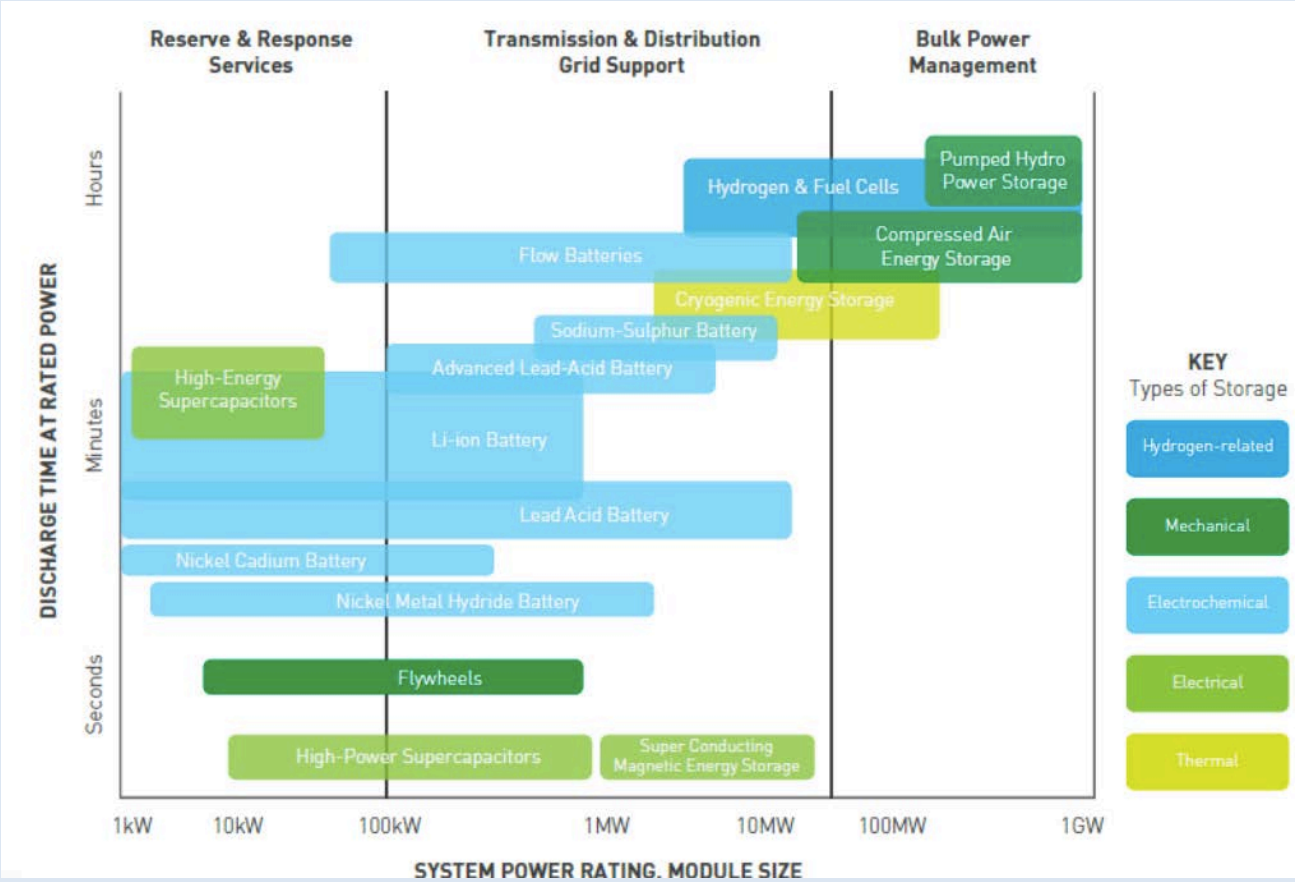
**Figure 1: Energy Storage Technologies by Power System Value Chain Support**




Source: Energy Storage Association, adapted from U.S. Department of Energy and EPRI 2013 Electricity Storage Handbook

- **Flywheel:** Flywheels are mechanical devices that use rotational kinetic energy to both store and discharge power. They can be charged relatively quickly.

- **Lead-Acid Batteries:** Lead-acid batteries are the most commercially mature rechargeable battery technology available. Lead acid batteries, however, are relatively short-lived, with life-spans of about two years. Before the development of valve-regulated lead-acid (VRLA) batteries, lead-acid batteries required frequent maintenance. They do not offer strong value propositions for utility-scale storage.

- **Lithium-ion Batteries:** Lithium-ion technology is relatively new, but it has become the foundation for many storage projects in recent years. Lithium-ion battery costs have decreased significantly in recent years, which has contributed significantly to new installed-capacity of storage.

- **Sodium-Sulfur (NaS) Batteries:** Sodium-sulfur battery technology holds potential for use in grid services because of its long discharge period of approximately 6 hours. It is capable of prompt, precise response to grid needs, but must be operated at high temperatures, which can be problematic for intermittent uses. Most NaS batteries are currently manufactured by a Japanese company, NGK.

- **Flow Batteries:** Unlike the solid-state batteries described above, flow batteries can store energy in liquid form or in external tanks, and collect or release power by having those liquids exchange ions through a special membrane. The most advanced flow batteries are vanadium redox batteries (VRBs). Vanadium's advantage is that its ions are stable and can be cycled through the battery over and over without undergoing unwanted side reactions. On the other hand,



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vanadium is costly, and VRBs have relatively low energy density.

**Applications**[2]

Energy storage plays roles in the generation, transmission and distribution aspects of the electric power system. Although the most obvious application for energy storage may be the balancing of intermittent generation resources, applications for storage are diverse. Firms looking to acquire energy storage technologies are not limited to generators and vertically integrated utilities. Developers, utilities, policy-makers and advocates are piloting energy storage to better understand from where in the electricity value chain the greatest economic value will be derived in order to justify the cost.

It is important to consider that deployment of one device may be used for multiple applications, thereby increasing the number of available revenue streams. As outlined in Figure 9, technologies have a few key features that inform their deployment for specific applications. Three components that inform the choice of technology for a specific application include:

- Speed the energy can be deployed, or discharge rate
- Amount of power deployed (e.g. kilowatts)
- Duration power can be sustained (seconds versus hours)

The following represents a selection of applications that ITA identifies as strongly amenable for storage.

- **Arbitrage:** Storing low-priced energy during period of low-demand and selling it during high-priced periods

- **Frequency regulation:** Regulations mandate that the AC frequency of grids be held within certain frames. Storage that can be deployed automatically and quickly (generally with a 1 minute response time) helps grids keep continuously shifting supply and demand within a control area.

- **Load following:** Similar to frequency regulation in that load following manages systems fluctuations, it differs in its longer time frame, which can range from 15 minutes to 24 hours.

- **Voltage support:** The injection of power to maintain voltage levels in the T&D system under normal conditions.

- **T&D congestion relief and T&D infrastructure investment deferral:** Storage is used to increase energy supply by increasing the load-carrying capacity of a T&D system. It relieves congestion points in the T&D grids and can defer the need for an investment in infrastructure.

- **Demand shifts and peak reductions:** Demand for energy peaks dramatically a few days a year, generally during hotter days, leaving the grid to operate at a lower capacity the remainder of the year. Storage reduces the need for additional capacity to serve peak demand and increases the efficiency of a grid's capacity.

- **Off-grid or low-grid:** Storage increases the reliability of energy supply in off or low-grid communities, especially when paired with renewable resources.

- **Renewable resources integration:** Storage is coupled with solar or wind installations to provide home consumers and utilities a way to use their intermittent sources around the clock and/or year-round.

**Selected Global Storage Market Case Studies**

Currently, the United States, Japan and Korea account for over 50 percent of the global energy storage market. ITA anticipates that opportunities in energy storage will continue to grow in these and other countries from the confluence of decreasing costs, increased understanding of storage's role in the power grid and a global commitment to cleaner energy.

Demonstration projects and pilot programs are moving forward across the country – including in California, Hawaii and West Virginia – and are being carefully studied and evaluated for market applications. ITA expects an increase in the number of demonstration projects in the near-term.

ITA assesses that near-term economic deployment of storage products will be primarily focused on support for ancillary services, such as frequency regulation. In the long term, creative and flexible deployments of



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storage will be necessary to capture all of the unique and varying benefits.

In lieu of sub-sector rankings, ITA examines market statuses for a small selection of countries. These evaluations are provided below.

- **Japan:** Japan is the largest residential energy storage market in the world with 277 MWh. This is supported largely by a behind-the-meter storage subsidy program that boosted sales of lithium-ion batteries.[3] Korean producers have benefitted from the subsidies, which have not been renewed for 2016. Significant reforms in Japan's electricity market, which until now has been dominated by the country's 10 vertically-integrated power companies, are bringing new opportunities for U.S businesses to tap into the liberalization of a $67 billion Japanese retail market. As the Japanese electricity market is reshaped, there will be opportunities for U.S. energy storage product manufacturers to offer a variety of storage solutions to utilities as well as residential consumers.

- **China:** There are over 50 energy storage demonstration projects in the planning and operating stages in China. The country is already using batteries to smooth wind and solar outputs, and it is expected to introduce other large-scale energy storage technologies to meet growing energy and flexibility needs. Similar to the United States, China is evaluating how to classify, use and regulate energy storage as part of generation, load management, and/or T&D. Despite China's heavy clean energy investments, it is still behind the U.S. when it comes to energy storage technology. China's 13th Five Year Plan, to be released in March 2016, has a renewed commitment to clean energy and specifically includes storage.

- **Germany:** Battery-makers such as Tesla have benefitted from Germany's rebates for solar-plus-battery household systems. The rebate program has returned 30 percent of the cost of the system, an average of $4000, to households, and was coupled with low-interest loans for other various renewable energy storage systems. When the subsidies expired in November 2015, Germany announced that this was because the goal of encouraging more solar-plus-storage systems had been met. The decision, however, was reversed only a month later. Lawmakers are now pushing for another three-year extension for the subsidies.

- **Australia:** Australia is emerging as a ripe market for energy storage. The country leads the world in residential solar penetration (15 percent), which presents an opportunity for large-scale household deployment of storage. BNEF reported that the average residential storage system cost fell from $2700/kWh in 2014 to $1000/kWh in 2015. With high electricity costs, Australia is particularly suitable for storage systems that offer good value propositions for households. Storage can also be applied to help defer T&D investments and service Australia's micro, low and off-grid communities.

- **Korea:** KEPCO plans to deploy 500 MW of energy storage for frequency regulation by 2017. This includes three projects in Kokam, Korea that have already been deployed: two lithium nickel-manganese cobalt (NMC) oxide energy storage systems (ESS) at 24 MW (9 MWH) and 16 MW (6 MWH) and a 16 MW (5 MWH) lithium titanate-oxide (LTO) ESS. These projects are the largest frequency regulation NMC ESS and LTO ESS globally and, together, are estimated to save KEPCO $13 million annually by reducing the amount of fuel purchased.[4] Lithium-ion batteries are driving the project, which is no coincidence as Korea has become a dominant player in this sector. ITA projects that Korea, along with Japan, will continue to innovate and drive down the costs of lithium-ion batteries.

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[1] Definitions are taken from following unless otherwise stated: Sandia Report SAND2013-5131 -- DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA; Energy Storage Association.
[2] Definitions are taken from following: International Energy Agency (2014), Energy Storage Technology Map Report; Energy Storage Association.
[3] Bloomberg New Energy Finance. *Global Energy Storage Market Outlook*, 2015.
[4] Smart Grid Today, *Kepco regulation reaches 56 MW with 2 new Kokam systems*, 7 March 2016



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