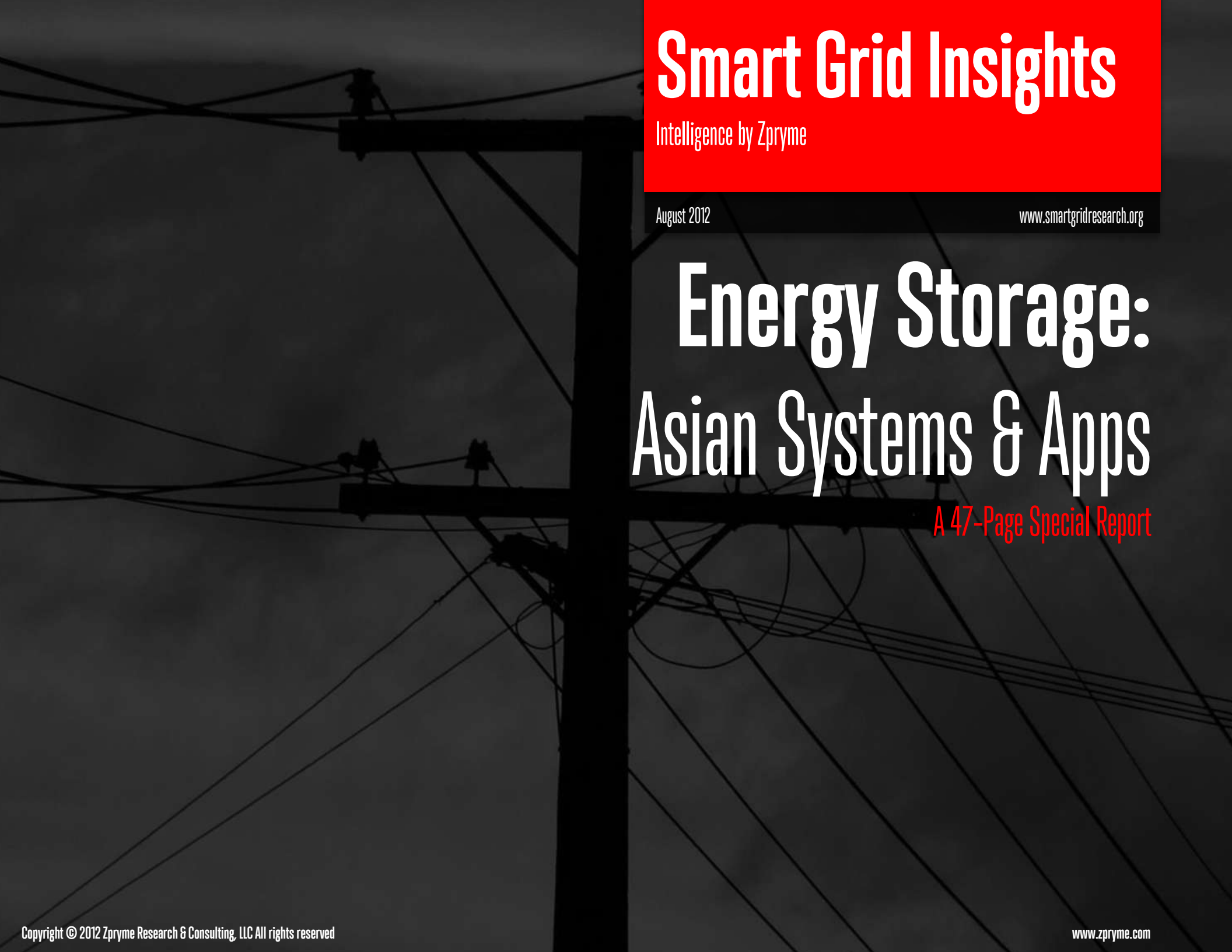

Smart Grid Insights

Intelligence by Zpryme

August 2012

www.smartgridresearch.org

Energy Storage: Asian Systems & Apps

A 47-Page Special Report

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Executive Summary

Energy storage has long been the missing link for end-to-end Smart Grid deployments, but is now poised for rapid growth over the next several years. The underlying technologies have been evolving for some time, but a dynamic ecosystem of applications is now in place that can address storage challenges such as grid communications, intelligent network monitoring, and the integration of renewable sources into the Smart Grid.

Nowhere is the opportunity greater – and the need more pressing – than Asia, which faces a unique set of challenges. The combination of limited energy infrastructure, large population and rapid industrialization creates a demand curve that Asian utilities cannot satisfy without an infusion of innovation.

Nothing speaks to this need for innovation better than energy storage, without which utilities will need decades to expand their infrastructures just to keep pace, and that is simply not a viable option. As Asian telecom operators have learned, it is far better to leapfrog the past by adopting new technologies. This same thinking has made Asia the world leader in areas that benefit from energy storage such as biomass, thermal power, microgrids, fuel cells and electrochemical battery technologies.

In this regard, Asian utilities are taking a smart approach with Smart Grid, and we expect energy storage will give rise to new business models and a more sustainable path for meeting the ever-growing needs of the region.

This report is the first of its kind to evaluate the energy storage opportunity, not just for the region, but also the key markets within it, namely, China, Japan, South Korea and India. To help utilities make better investment decisions, our report examines the systems and applications that comprise energy storage solutions, as well as profiling the leading global technology vendors serving this market. This report has been developed by Zpryme's Smart Grid Insights Research Team and Zpryme's Smart Grid Advisory Board.

Key Takeaways by the Numbers

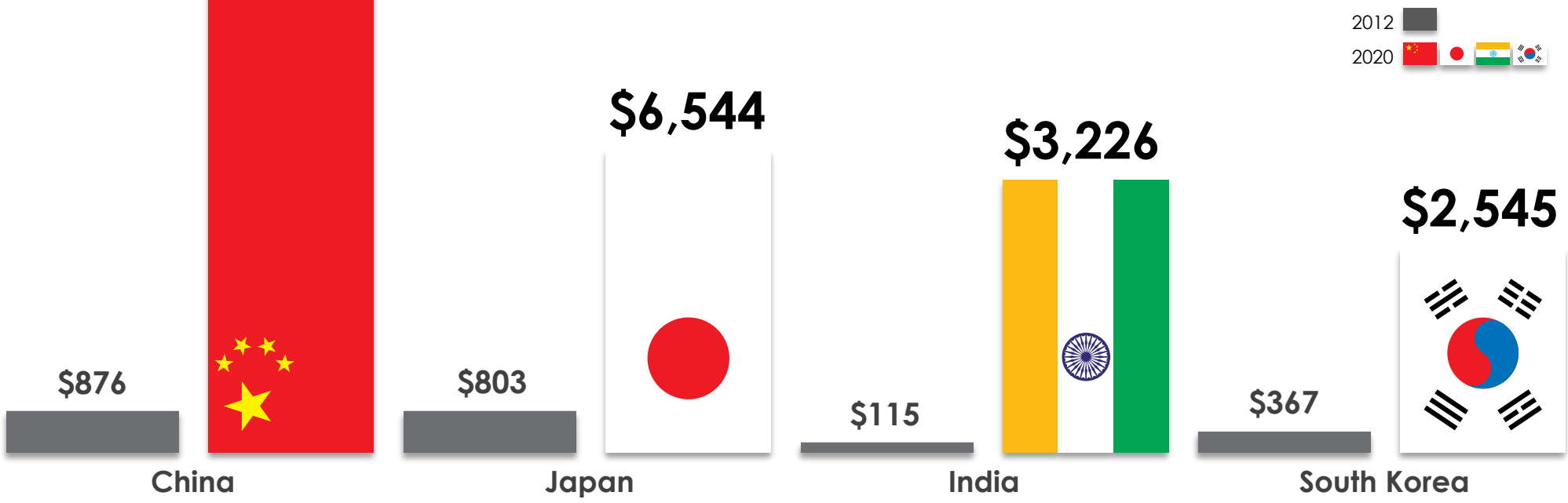
The global grid-scale energy storage systems market is projected to reach $7.3 billion in 2012. By 2020, the global market is projected to reach $67.0 billion. The market is projected to grow at a compound annual growth rate (CAGR) of 32%.

In 2012, Asia's grid-scale energy storage market is projected to reach $3.6 billion. By 2020, the Asia market will reach $36.4 billion, growing at an annual rate of 34%. In 2012, Asia is projected to account for 49% of the global market. By 2020, Asia will account for 54% of the global market.

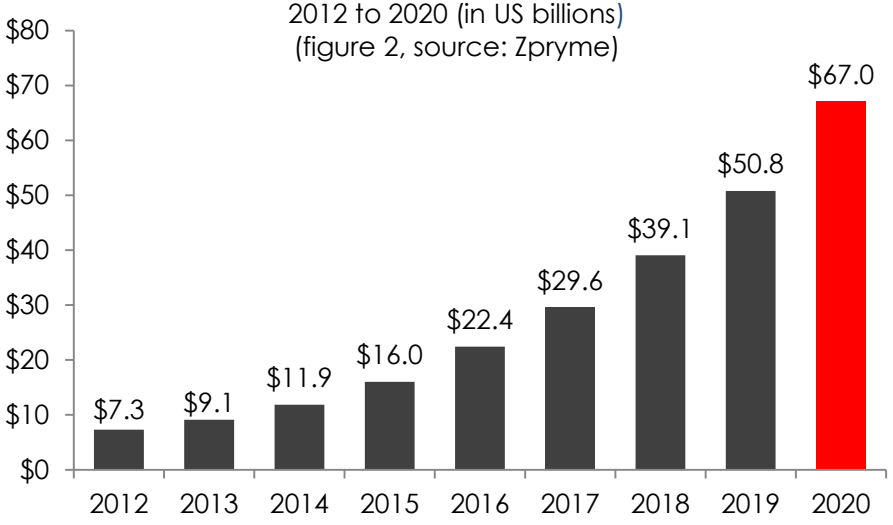
- By 2020, Asia's advanced batteries, pumped hydro, and other (CAES, Flywheels, etc.) segments are projected to reach a market value of $10.9 billion (30% of the market), $21.1 billion (58% of the market), and $4.4 billion (12% of the market), respectively.

How well do you know the Asian energy storage ecosystem?

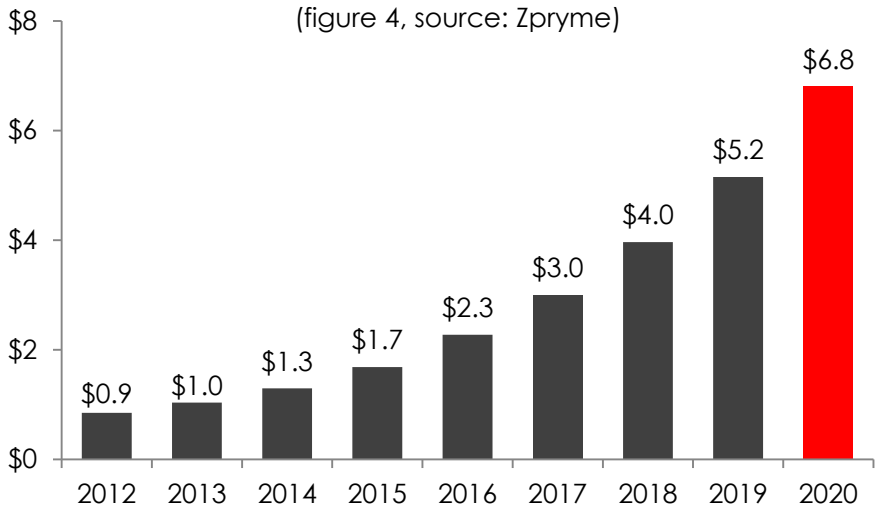
Grid-Scale Energy Storage System Forecast by Country, 2012 – 2020
(figure 1, source: Zpryme, in US millions)



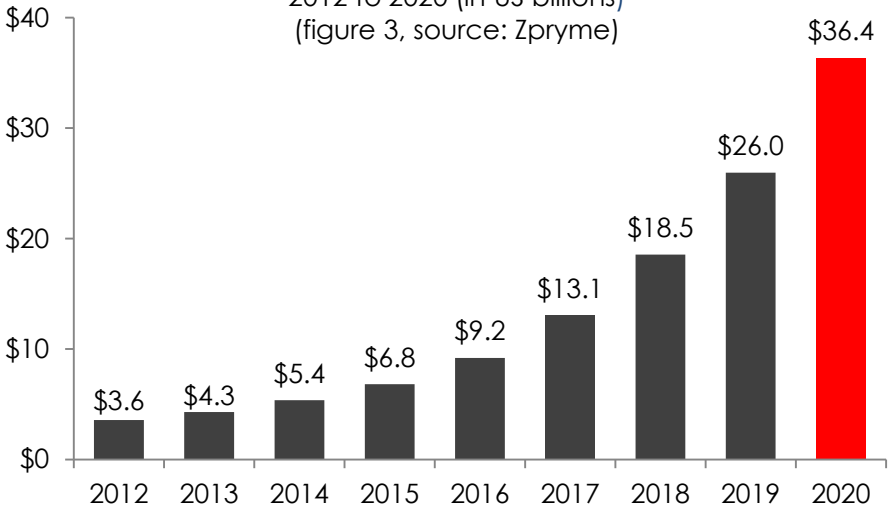
Global Grid-Scale Energy Storage Systems
Market Value Forecast
CAGR = 32%
2012 to 2020 (in US billions)
(figure 2, source: Zpryme)



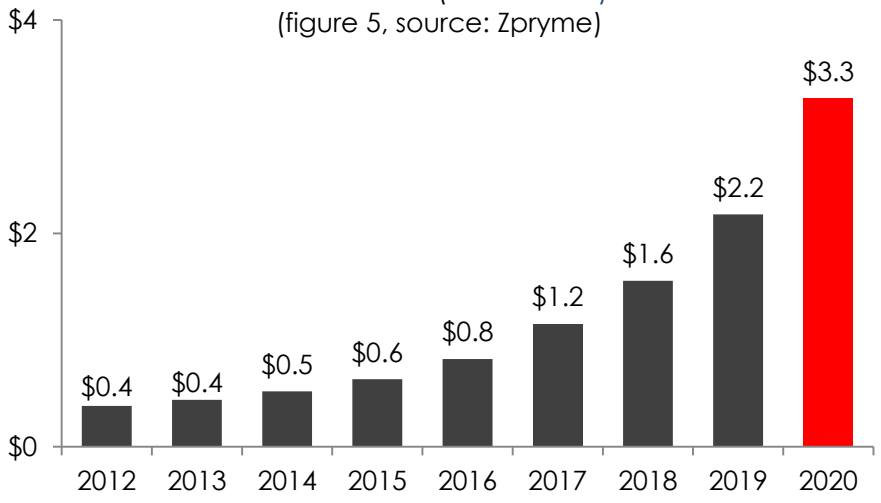
Global Applications for Grid-Scale Energy Storage
Market Value Forecast
CAGR = 30%
2012 to 2020 (in US billions)
(figure 4, source: Zpryme)



Asia Grid-Scale Energy Storage Systems
Market Value Forecast
CAGR = 34%
2012 to 2020 (in US billions)
(figure 3, source: Zpryme)



Asia Applications for Grid-Scale Energy Storage
Market Value Forecast
CAGR = 31%
2012 to 2020 (in US billions)
(figure 5, source: Zpryme)



- By 2020, Asia's lead acid, molten salt, and Lithium-ion battery technologies are projected to reach a total value of $4.0 billion, $3.3 billion, and $2.7 billion, respectively.

Energy storage systems will need enabling applications to automate, manage, monitor, and control their integration into utility systems. In this report, enabling applications included in the market value forecasts are integration software, intelligent electronic devices (IEDs), communications and networks, sensors, and battery monitoring systems.

- From 2012 to 2020, the global market for enabling applications for grid-scale energy storage systems is projected to grow from $0.9 billion to $6.8 billion.

- From 2012 to 2020, the Asia market for enabling applications for grid-scale energy storage systems is projected to grow from $0.4 billion to $3.3 billion. In 2012, Asia is projected to account for 45% of the global market. By 2020, Asia will account for 48% of the global market.

    - By 2020, the Asia market for renewable integration software, IEDs, and communications networks are projected to reach $51 million, $70 million, and $555 million, respectively. By 2020, the market value for sensors and energy storage monitoring systems are projected to reach $817 million and $1.1 billion, respectively.
    -

Recommendations and Opportunities

Recommendations

1. Regardless of how advanced Smart Grid plans are, Asian utilities can benefit considerably from energy storage technologies and applications. To assess the value, they must first understand how energy storage impacts the full value chain across generation, transmission and distribution. Energy storage is not a niche solution, and has applications across the full Smart Grid spectrum.

2. Utilities need to view energy storage as an enabler of efficiencies for Smart Grid that could not occur otherwise. In this regard, energy storage can truly make the pie larger, opening up new opportunities to serve customers and generate new revenues.

3. Energy storage solutions have been evolving for years, and will continue to do so. These technologies are far from reaching their potential, but can deliver enough benefit today to be compelling for utilities. Energy demand will outstrip supply in Asia for years to come, and these solutions can play a key role now in helping utilities keep pace.

4. Many paths can be taken with energy storage, and utilities needs to think strategically about their priorities. Some solutions can reduce costs by making the grid more efficient or enabling microgrids that reduce the need for carbon-based energy. Others can yield new revenues by

extending power to locations that either had no energy before, or ensuring a more reliable supply.

5. For energy storage and applications vendors, the specific needs of the Asian market need to be well understood. This is a large and fast-growing region, but generally lacks First World infrastructure, and can be hampered by complex regulations and bureaucracies. Asian utilities are amenable to all vendors, but require them to move quickly and address large scale requirements.

Opportunities

1. Much of Asia is either not connected to the grid or has unreliable sources of power. The recent large scale power outages in India are but one example, and energy storage has a key role in helping utilities serve their customers in new and better ways.

2. Asia's large and growing population is placing unprecedented pressure on utilities to meet demand, and they cannot do it with the status quo. Even though the technologies are still evolving, energy storage presents a myriad of options that utilities can pursue right now.

3. To whatever degree Asian utilities are supporting the Kyoto Protocol, the need to reduce their carbon footprint will only grow. This is a key driver for renewable energy, and storage technologies have a central role to play in making these sources viable.

4. Distributed generation and microgrids present opportunities for new business models that do not rely on the traditional mode of centralized power generation. Small scale and localized forms of energy become feasible with storage technologies, and savvy utilities will see this as a new way forward, reducing the need for costly infrastructure upgrades.

5. Despite the attraction for moving to renewable energy, conventional sources will remain dominant for years to come. As the demand for energy grows, these sources will become more costly, requiring utilities to reduce operating costs. Energy storage applications can improve efficiencies in many ways and help keep costs in line.

6. Smart Grid initiatives are quite advanced in Asia, and renewable energy is a cornerstone for any utility in this regard. Energy storage is a key enabler for renewable energy and distributed generation, making this an attractive opportunity for Asian utilities.

The Smart Grid and Energy Storage in Asia

Energy storage technology is a vital part of the Smart Grid in Asia. As the Smart Grid is further deployed, the energy storage market will experience tremendous growth. This increase is driven by a need to extend energy into areas that are currently not connected to the electrical grid. There is also tremendous pressure to improve energy efficiency, as well as reduce greenhouse gas emissions and reduce energy losses. Every Asian country has developed plans to install a Smart Grid. An essential part of successful Smart Grid deployment is the inclusion of energy storage, as it allows the firm to leverage the unused energy created during non-peak periods, allowing it to be used when needed. In fact, energy storage is an essential component of the Smart Grid, as it allows reliable energy transmission, and it will become an inherent component of the Smart Grid in the long term.

Utilities that utilize energy storage will experience many benefits, including more reliable and efficient operations, as well as fewer outages. In addition, the utilities will be better equipped to incorporate distributed energy, microgrids, and renewable energy resources. Energy storage is able to be applied in several ways and offers many benefits for the country that effectively employs it. Although energy storage is in its early stages in many Asian countries, the research being conducted in areas such as South Korea and Japan will likely reduce the cost and increase the operating efficiency of storage technologies, further supporting the development of the field. Firms that are able to meet the need for energy storage deployment in Asia, as well as foster key alliances with the government and utilities in Asia, will be best poised to take advantage of this growing trend for energy storage projects, and can experience the financial benefits as the market grows and additional energy storage is deployed throughout the continent.

Asia currently has over 60 GW of cumulative installed energy storage capacity making it the largest base of energy storage worldwide, a title it is likely to maintain as additional deployments of the Smart Grid spur further deployments of energy storage technology. Several Asian countries have begun to experience the effects of the Smart Grid on energy storage. Japan and South Korea have two of the most developed Smart Grids in the world and are now conducting extensive research in energy storage that will not only be deployed in Asia, but throughout the world. For example, Japan has deployed sodium sulfur batteries for grid scale energy storage. Currently, China has several energy storage partnerships in key locations in Zhangbei, Shenzhen City and Chennai to support its Smart Grid infrastructure. In addition, China is conducting several pilot projects to further investigate the potential for usage and develop a business case for energy storage in the Smart Grid. Singapore also has plans to deploy energy storage to support its Smart Grid infrastructure, requiring at least 0.1 MW in the near term. As the Smart Grid is deployed in a larger capacity, nations are better able to focus on the deployment of energy storage technologies in support of its Smart Grid infrastructure.

Benefits of Energy Storage for Utilities

Energy storage holds numerous benefits for utilities that employ it. Among these benefits are a reduction in the

number of outages, and a more efficient and reliable grid. Also, the firm is better able to match the supply and demand of energy in the grid, and provide improved energy management of the grid itself. The firm will also benefit from being able to delay expensive improvements, and be better able to implement renewable energy generation. Many areas of Asia experience frequent outages and inconsistent energy transmission. Energy storage addresses these issues in many ways. First, energy storage provides voltage and frequency regulation, as well as VAR support. Stored energy is able to absorb excess voltage and release energy when the transmitted voltage is insufficient. This improves the power quality and creates a more reliable grid. In addition, stored energy acts as a spinning reserve and provides ride-through protection, since it can provide several hours of energy support to the grid and its stored energy can be released immediately. This eliminates both momentary inconsistencies and longer lasting outages, thus improving the reliability of the grid. Another problem frequently faced in Asia is matching energy supply to energy demand. Energy is wasted during non-peak periods when supply exceeds demand, and outages are experienced when demand exceeds supply. Energy storage is very effective at meeting this need because it allows energy to be time-shifted. This occurs when excess energy is stored during non-peak periods and utilized during peak periods when demand is greater.

Energy Storage as Distributed Generation

Distributed generation is gaining momentum in Asia. One main benefit of distributed generation is that energy is produced closer to the point where it is consumed. This lowers the distance energy is transmitted and thus lowers transmission losses. However, this also means that energy is produced outside of a centralized plant, where supply and demand can be monitored. Therefore, it is vitally important that energy be stored when it is produced in excess and disbursed when it is needed. Energy storage allows distributed generation to run at a constant level, even if the energy that is generated fluctuates. In addition, distributed generation can provide energy in areas that currently do not have access to energy. Energy storage allows generated energy to be stored in these locations for use when needed. Utilizing energy storage with distributed generation resources to alleviate poverty and provide energy security for local residents has encouraged several Asian countries to undertake pilot projects utilizing energy storage along with distributed generation.

China, for example, has several small scale thermal power plants that produce less than 6 MW. Also, China has a network of distributed small hydro power plants that provide supplementary power to the electrical grid. Deploying energy storage to store excess energy produced in these small facilities would increase their value and extend their generation capacity impact.

In Japan, several types of distributed generation are used nationwide, the largest of which is biomass power generation, which is a byproduct of manufacturing paper. Japan employs several types of fuel cells to provide energy from distributed resources, including 1 KW of commercialized Polymer Electrolyte Fuel Cells. Energy storage became much more important in combination with distributed generation following several natural

disasters in 2011. Immediately several manufacturers offered different types of batteries to be used in distributed buildings and communities as the centralized Tokyo Electric Power Company's generation capacity was reduced and thus unable to meet electric demand. Areas in which energy storage already supported its electrical grid were able to utilize that back-up source of power when energy was disrupted, and maintain critical operations during this emergency.

India is also looking to energy storage and distributed generation to meet its energy needs. India realizes that combining distributed generation with energy storage improves the overall operation of the electric system. The National Thermal Power Corporation (NTPC) investigated utilizing a combination of distributed generation with energy storage in the electrification of villages near existing thermal power stations. Huawei, India has employed both batteries and diesel generators to provide back-up energy storage, but also recognizes the problems that could be incurred by these methods. For that reason, the Indian research advocates utilizing fuel cells, especially in distributed generation locations that experience frequent outages.

Energy Storage in Microgrids

One branch of energy generation that takes advantage of distributed generation and energy storage is microgrids. A microgrid is a closed energy system that can operate either independently or attached to the electrical grid. Microgrids are particularly attractive when establishing energy in remote locations, where it may not be feasible, or even possible to connect to the electrical grid. In some locations, diesel generators provide energy to the microgrid, however renewable resources are becoming increasingly used to provide power to rural communities. No matter what technology is used in the microgrid, energy storage is extremely important to enabling its success. Employing energy storage allows the microgrid to be self-contained by enabling energy produced at one time to be consumed at another.

Several Asian countries have deployed microgrids. Japan was one of the first countries worldwide to research and deploy microgrids, establishing itself as an expert in the field. One example of a microgrid is located in Sendai, Japan. After the devastating earthquake and tsunami struck the town of Sendai, much of the town was without power; however the Tonoku Fukushi University, including its hospital and laboratory, was powered by its microgrid and remained energized. The Sendai microgrid employs thermal energy storage to provide reliable and consistent power to the microgrid. The project has successfully demonstrated the reliability of a microgrid, even during natural disasters and times of emergency.

Huawei, China provides another example of an Asian microgrid and serves as an example of microgrid use in different settings, such as homes, governmental agencies, hospitals and schools. The research conducted in Huawei includes energy management technology, fuel cells, and energy storage systems. Huawei holds patents for several energy storage methods including superconducting energy storage, micro compressed air energy storage, and cold energy storage. Finally, Huawei's research center has its own microgrid, operating the microgrid and energy storage it develops.

Another example of a microgrid being supported by energy storage systems is in Rampura, India. Rampura distributes power through its microgrid that is generated through the first community-managed solar power plant in India. The plant includes 60 photovoltaic panels, each of which produces 145 W of energy. The array is supported by a 24 cell battery bank that produces 2v each for its energy storage needs, providing uninterrupted power back up for 4-5 days without sun.

Energy Storage and Renewable Integration

Two key areas that have prevented the widespread adoption of renewable energy are its inability to maintain a constant generation amount and its inability to store energy for later use. Energy storage meets both needs as the backbone for widespread renewable energy integration. In fact, renewable energy integration has spurred further deployment of energy storage technology, as energy storage mitigates the risks experienced by intermittent energy generation. Wind energy experiences random fluctuations in generation, which produces problems in the system, problems which energy storage can alleviate. Energy storage also is needed to provide energy for periods when solar and wind are not available, such as at night. Renewable energy is being pursued in Asia for several reasons, including reducing greenhouse gas emissions, reducing dependence on oil and coal, and increasing energy production. Renewable energy improves energy security and improves the diversity of the grid's energy mix. For these benefits to be realized, energy storage is absolutely essential for the further development and deployment of renewable energy sources. In fact, renewable energy integration is a key driver in energy storage deployment. And as Asian countries continue to be driven toward higher levels of renewable energy integration, spurred by policies such as the Kyoto Protocol, the energy storage market will experience greater growth. As the energy mix experiences greater quantities of renewable energy, especially intermittent energy like solar and wind energy, the larger the market for energy storage will be.

All Asian countries have deployed renewable energy resources, and energy storage technology has been deployed with it. China is the largest producer of wind energy, providing 41.83 GW capacity. However, the Chinese Renewable Energy Industry Association stated that the grid connected capacity is currently operating at 30% below installed capacity. For the full benefits of its potential to be realized, energy storage must be deployed in conjunction with wind generation. The State Grid of China has also entered into agreements to install several large scale energy storage facilities to be used in conjunction with renewable energy resources. In Zhangbei, 36 MW of battery storage will back up 100 MW of wind and 40 MW of solar energy production. In addition, 120 MW battery storage will be added to renewable energy resources in the Longgang District of Shenzhen City. Both projects have been encouraged by China's Golden Sun Initiative which supports the widespread generation of solar energy, and thus the energy storage that enables it.

Energy Storage Applications

Power storage technologies are used globally for various power management applications; including load leveling, demand response, and transmission support. The International Energy Agency (IEA) identifies four prominent types of grid-scale power storage applications based on the supply duration of stored power: power quality management, load shifting, power bridging, and bulk power management. Both small-scale and large-scale projects utilize the several types of storage technologies that are available in the market today.

Power Quality Management: Power quality management, or frequency management, has the shortest operating time span (as short as one millisecond) of all storage applications. Electricity demand changes constantly, altering the power frequency of transmitted electricity and creating demand-supply mismatch. It is imperative to maintain a consistent power profile and match the fluctuations in power demand immediately because variations in power frequency may cause damage to user-owned appliances. Also, renewable energy sources heavily depend on weather conditions and are susceptible to major power frequency variations. As integration of renewable resources is rising, the possibility for fatal power frequency variations is increasing, and the need for power storage technologies. SMES, FES, and advanced battery systems are utilized in power quality management due to their quick response times.

Load shifting: Load shifting is used in demand side management, and reduces the size of peak loads by using stored power that is produced during off peak hours when demand is high. Power demand varies based on collective energy use, and results in different power load requirements. Power storage technologies suitable for load shifting have longer power supply durations, such as lithium-ion (Li-ion) batteries, sodium-sulfur(NaS) batteries, and flow batteries (Fbs).

Power bridging: Power bridging uses storage technologies to fill the gaps in power generation that is caused by the intermittency of renewables due to weather conditions, which drastically deteriorate output and restrict growth. Large scale generators fluctuate output to account for intermittent generation, sacrificing generator efficiency, increasing costs, and producing higher emissions. Likewise, load leveling mitigates changes in generator output resulting from real-time signals in constantly fluctuating customer demand. Energy storage technologies reduce these swings and maintain the efficiency of generation output, by injecting or absorbing electricity from the grid. Since intermittency may last for hours, longer power supply durations is necessary, making NaS batteries and FBs desirable for power bridging and load leveling. Duke Energy's wind farm has 986 MW of wind capacity, and uses a 36 MW Xtreme Power energy storage system to help smooth the variable generation output.[1]

Bulk Power Management: Bulk power management stores excess power generated (up to 24 hours) for use when energy is in demand, such as storing excess energy from renewables for use during times of intermittency, which can reduce the use of fossil-fuel power plants. Demand

[1] www.bloomberg.com/news/2011-04-14/duke-building-largest-storage-system-with-xtreme-at-wind-farm.html

Response applications, consumer-focused programs that store excess non-peak energy for use during peak periods, allows software to communicate and coordinate with different energy storage systems. Transmission applications absorb and inject energy from the grid to compensate for electrical disturbances such as voltage sag, unstable voltage and sub-synchronous resonance, as well as reduce congestion and reduce equipment burden, possibly avoiding costly system upgrades that would be necessary due to incremental demand increases. Presidio, Texas was able to alleviate congestion and avoid a costly new transmission line by installing a 4MW NaS battery[2]. Pumped hydroelectric storage (PHS) and compressed air energy storage (CAES) have long power supply durations and are the two power storage technologies with the most potential for bulk power management applications.

Small Scale vs Large Scale Storage

In addition to many of the grid applications discussed above, there is a growing market for smaller sized energy storage systems. A good rule of thumb is that an energy storage system under 1 MW will be considered grid storage, while smaller systems will be considered consumer-side storage. As more utilities institute dynamic pricing schemes, residential consumers are using small energy storage systems to manage their electricity bill over the course of a fluctuating billing period. These systems can be exponentially valuable when paired with a solar photovoltaic system. Additionally, commercial consumers may desire a smaller-scale energy storage system to reduce their 'demand charge'. Some commercial consumers are charged a baseline fee based on the peak usage during a month. A consumer using a small scale battery system can offset their peak usage reducing their overall demand change.

Finally, small-scale energy storage systems are being used to replace traditional back-up supply technologies. Critical loads, for instance an operating room in a hospital or a semi-conductor manufacturing facility, may need to guarantee electricity if the grid fails to deliver. The varying battery technologies and applications are still in the process of fully maturing and fitting into the most efficient business models. While the industry continues to segment and advance, it is clear that batteries used for electric energy storage will continue to be an important part of the energy industry for the coming decades.

Prominent Electrochemical Technologies

Utilities and companies make decisions based on the specific needs of particular projects, choosing from an array of cost-competitive battery technologies. The IEA states the capital costs of power storage technologies range from $380 to $8,200 per kilowatt.

Lead-acid batteries: Lead acid batteries, familiar as car batteries, are over 100 years old and are the oldest technology available.[3] They are relatively low-cost, rechargeable, readily available, and can provide instantaneous response. They are attractive for large-scale power storage applications, including power quality, frequency regulation, uninterrupted power supply and spinning reserve. Valve-regulated lead-acid batteries offer power storage ratings of 20MW, and are the least

[2] www.ettexas.com/projects/docs/NaS_Battery_Overview.pdf.

[3] www.huffingtonpost.com/dan-r-fink/solar-electric-backup-for_b_1696535.html

expensive choice costing $950-$1,590 per kilowatt, or $2,770-$3,800 per kilowatt-hour.[4] However, they are susceptible to low temperatures, have a low specific energy, do not handle many deep discharges and have a short calendar and cycle life.[5]

Nickel batteries: Nickel batteries generate power through nickel hydroxide electrodes, are lightweight and offer good energy density, ranging from 20Wh/kg to 120Wh/kg. They cost $300-$500 per kilowatt-hour,[6] with an efficiency range of 70%-90%. Improved manufacturing productivity and capacity utilization could reduce cost.[7] The two most advanced applications include nickel-cadmium (Ni-Cd), nickel-metal hydride (Ni-MH), while nickel-zinc (Ni-Zn), and sodium-nickel chloride (Na-NiCl2) are at an earlier stage of development. Ni-Cd offers a greater range of operating temperatures, needs less maintenance, improves cycling ability and has a long life[8]. In 2011, the US had 26 MW of Ni-cd.

Molten Salt Batteries: Molten salt batteries, high temperature electric batteries, and are seen as the next best contender behind li-ion,[9] offering economically attractive vertical growth by 2015. The mature technology has an "excellent cycle life"[10], because of high energy, efficiency, power density, and long discharge durations, but are costly (around $1,000 per kilowatt-hour,[11]) and have safety problems due to temperature management issues. NaS applications include peak shaving for T&D upgrade deferral and small load leveling applications.[12] Manufacturing improvements and better capacity utilization could produce a 95% cost reduction, making NaS batteries the cheapest option.[13] In 2011, NaS batteries made up 18MW of the US grid[14], and the chemistry was dominated by Japanese firms like NGK. General Electric has invested significantly in production of sodium sulfur batteries.

Flow batteries (FBs): FBs are a relatively new class of battery, available in three main types: zinc-bromide FBs, vanadium electrolytes FBs(VRFBs) (both in the early stages of commercialization), and sodium-bromide Fbs (currently under development). FBs store large amounts of power (tens of kilowatt-hours to tens of megawatt-hours) and offer highly flexible delivery output over several hours or within milliseconds, making it suitable for a wide range of applications, from bulk power management to power quality management. Flow batteries cost $100-$500 per kWh,[15] however deploying inexpensive metal electrodes and utilizing high volume metal production manufacturing processes that can offer cost reductions.

Lithium-ion batteries: Lithium-ion batteries are prominently used in consumer electronics and offer one of the best energy-to weight ratios, are light weight, power intensive, have high output voltage, exceptional cycling capability, deep discharge capabilities, and are able to maintain a charge for long durations when not in use. They are preferred for space-constrained projects because of their

[4] gigaom.com/cleantech/5-things-you-need-to-know-about-energy-storage/
[5] Market Analysis of Emerging Electric Storage, 2008
[6] insideclimatenews.org
[7] www.pv-magazine.com
[8] (http://www.saftbatteries.com/Technologies_Nickel_NiCd_293/Default.aspx)
[9] news.cnet.com/8301-11128_3-10380239-54.html
[10] (Market Analysis of Emerging Electric Storage Systems DOE/NETL-2008)
[11] newenergyandfuel.com/http:/newenergyandfuel/com/2011/10/10/a-battery-for-the-grid/
[12] Market Analysis of Emerging Electric Storage, 2008
[13] Grid-storage-battery-cost-to-fall-to-500kwh-short-of-expectations-2012-07-03
[14](Energy storage activities in the...grid)
[15] gigaom.com/cleantech/behind-the-scenes-of-primus-powers-battery-lab/

high energy density, and cost around $1,085-$1,550 per kilowatt, or $4,340-$6,200 per kilowatt-hour.[16] Growth will be enabled by their use for remote off-grid storage, T&D deferral and industrial peak shaving increases.[17] Frequency regulation will drive growth, while price arbitrage and residential storage applications will increase as prices drop due to mass production, making them "economically attractive" by 2015.[18] In 2011 there was 54MW of li-ion storage in the US, with companies like A123 developing li-ion kits for grid storage.[19]

Fluid Storage: Fluid power storage systems, primarily PHS and CAES, convert electrical energy into a fluid stored for generation at a later time, and are widely used in large-scale power storage systems globally. However, the scarcity of geological formations suitable for the installation of fluid power storage technologies may significantly restrict the growth of these technologies. The installation costs range from $800 to $2,700 per kilowatt.

Pumped Hydro Storage (PHS): PHS converts electrical energy into hydrokinetic energy and stores it in a water reservoir. When power is needed, the water passes through a generator, providing energy management, frequency control, and reserve capacity.[20] The range of costs for Pumped-Hydro is $500/kW to $1500/kW, often economically viable for providing peak power for a system comprised mostly of fossil fuel and/or nuclear generation.

Compressed Air Energy Storage (CAES): CAES stores electrical energy in high-pressure air vessels and are used less frequently than PHS systems, mainly due to lack of suitable sites to install CAES projects. Recent advancements in the technology include above-ground storage in empty natural gas tanks and 'mini-CAES', and a transportable technology that can be installed at or near individual loads.[21] CAES has a capital cost of $1,500 per kilowatt.[22]

Flywheel Energy Storage (FES): FES converts electrical energy into kinetic energy, and is primarily associated with short-term power applications such as power conditioning. Flywheels are expensive, at $1,950-$2,200 per kilowatt or $7,800-$8,800 per kilowatt hour,[23] a cost that could be mitigated by technological developments through the installation of multiple FES systems.

Superconducting Magnetic Energy Storage (SMES): SMES systems can store and discharge energy continuously through a superconducting coil and continuous magnetic field, without converting energy into another form. This makes it the fastest power storage technology for power charge and discharge, which will drive the growth in short-term power frequency applications. The installation costs range from $380 to $490 per kilowatt. The technology is in the development stage in the US and Japan, and is likely to experience technological improvements that will reduce cost.

[16] gigaom.com/cleantech/5-things-you-need-to-know-about-energy-storage/
[17] BCG, "Revisiting Energy Storage" February 2011, Cornelius Piepper and Holger Rubel.
[18] (BCG).
[19] (Energy storage activities in the...grid)
[20] www.electricitystorage.org/technology/storage_technologies/pumped_hydro
[21] www.electricitystorage.org/technology/storage_technologies/caes
[22] www.greentechmedia.com/articles/read/compressed-air-energy-storage-beats-batteries/
[23] gigaom.com/cleantech/5-things-you-need-to-know-about-energy-storage/

Global Market Value Forecasts

Global Grid-Scale Energy Storage System Market Value Forecast, 2012 – 2020

(table 1, source: Zpryme, in US billions)

Market Value	2012	2013	2014	2015	2016	2017	2018	2019	2020	CAGR
Global Market	$7.3	$9.1	$11.9	$16.0	$22.4	$29.6	$39.1	$50.8	$67.0	32%
Asia	$3.6	$4.3	$5.4	$6.8	$9.2	$13.1	$18.5	$26.0	$36.4	34%
Asia % of Global Market	49%	47%	45%	43%	41%	44%	47%	51%	54%	

China, Japan, South Korea, and India Grid-Scale Energy Storage System Market Value Forecast, 2012 – 2020

(table 2, source: Zpryme, in US millions)

Market Value	2012	2013	2014	2015	2016	2017	2018	2019	2020	CAGR
Country										
China	$876	$1,183	$1,597	$2,155	$2,910	$4,219	$6,118	$8,870	$12,862	40%
Japan	$803	$1,028	$1,316	$1,684	$2,156	$2,845	$3,756	$4,958	$6,544	30%
South Korea	$365	$475	$617	$802	$1,042	$1,303	$1,629	$2,036	$2,545	27%
India	$115	$332	$432	$561	$730	$1,058	$1,534	$2,225	$3,226	52%
Total	**$2,159**	**$3,017**	**$3,961**	**$5,203**	**$6,837**	**$9,425**	**$13,036**	**$18,089**	**$25,177**	**36%**
% of Asia Market	60%	70%	74%	76%	74%	72%	70%	70%	69%	

Global Energy Storage Enabling Applications Market Value Forecast, 2012 – 2020

(table 3, source: Zpryme, in US billions)

Market Value	2012	2013	2014	2015	2016	2017	2018	2019	2020	CAGR
Global Market	$0.9	$1.0	$1.3	$1.7	$2.3	$3.0	$4.0	$5.2	$6.8	30%
Asia	$0.4	$0.4	$0.5	$0.6	$0.8	$1.2	$1.6	$2.2	$3.3	31%
Asia % of Global Market	45%	42%	40%	38%	36%	38%	39%	42%	48%	

Methodology

Zpryme utilized secondary research sources, publicly available sources, government announced plans, and utility Smart Grid and Energy Storage plans to analyze the Asia Energy Storage Market. In-depth industry interviews were also conducted to better understand the market drivers, demand, and opportunities. Qualitative assessments were made by Zpryme's research team that take into account both the primary research (meetings/interviews) and secondary research findings to assess the market segments of interest.

Finally, time series forecasting was used to project market values from the baseline data obtained from primary and secondary research methods. Other variables accounted for in our models include but are not limited to:

- Energy demand
- Energy/fuel prices
- Economic growth (GDP growth)
- Government stimulus
- Government goals
- Renewable generation targets
- Private sector capital investment.

Global Key Players

ABB: ABB has a platoon of product solutions for energy management:

- Their PCS 100 (ESS) energy storage system provides grid-connected energy to improve power quality and grid stabilization in compliance with renewable and generation systems.

- Their BESS (Battery Energy Storage System) provides spinning reserve in the event of power plant or transmission line equipment failure.

- Their DynaPeaQ energy storage solution which combines SVC Light performance with the latest battery storage technology to allow for a significant increase in renewable generation.

- Power conversion systems which charge/discharge the battery/ultracap/flywheel energy to and from the grid, as well as black start capability and dynamic control for applications such as peak shaving.

China ordered 10 PCS Energy Storage systems in 2011 for the supply of the Wind and Solar Energy Storage and Transmission Demonstration Project. The equipment will take care of the energy storage, wind and solar power output smoothening, scheduled generation, tracking, peak shaving and system frequency modulation.

In a recent order from Indonesia, ABB provided its first PCS100 energy storage solution for a flow battery system, manufactured by a Chinese industrial battery manufacturer, to supply necessary energy during grid operation in a micro-grid environment.

GE: With a product strategy of producing longer-term batteries, GE invested $100 million to produce the next-generation industrial battery technology. The result is the Durathon Battery, which is a sodium-nickel battery that is thermally sealed in ceramic enabling operation in extreme temperatures and without air conditioning. They are 50% smaller and 25% lighter than traditional batteries enabling more energy to be stored in a smaller space. They can be modularly configured and since the cells are recyclable, the batteries represent a sustainable technology.

GE's Durathon battery, backed by Durathon Battery Energy Storage Systems, is marketed for stationary and motive applications in telecommunications, power generation, grid operation, energy management and UPS systems. The batteries are good for ambient conditions and ideally suited for hot climates and off-grid locations, particularly in telecom applications with poor and unreliable grids, such as portions of Southeast Asia and remote China. GE also has a transportation concentration for mining equipment, locomotives, and heavy construction. The technology also blends well as a hybrid with diesel.

GE recently signed a business cooperation agreement with Arista Power, Inc., a manufacturer, designer, and integrator of renewable generation, management and distribution systems, to jointly market Arista's new Power on Demand System that will incorporate GE's Durathon batteries. GE has also agreed to acquire Converteam, a

world leader in power conversion technologies, which is collaborating with Prudent Energy to design and install Vanadium Flow Batteries for power grids in the US and China.

As a compliment to energy storage, GE has different control systems in the works around all areas, especially solar, DMS and EMS systems, Dynamic Response and Peak Load applications.

GE's near-term focus is to take the technology into mass production. In July, GE opened a manufacturing facility in Schenectady, New York which will eventually be served by 450 employees.

GE's first customer is a South African Company, Megatron Federal. The company will pair GE's batteries with diesel generators in an effort to save 53% on fuel, 45% on maintenance, and 60% on generator replacements.

SIEMENS: In conjunction with one of the world's largest manufacturers of lithium-ion rechargeable batteries, Siemens offers their "Siestorage" modular storage energy system for power distribution systems. Siestorage provides energy storage solutions for applications such as stabilizing distribution systems with a high proportion of distributed and renewable power generating plants, and supplying emergency power to vulnerable industrial production processes, computer centers and hospitals. Siemens is quite involved in supplying wind and gas turbines and flywheel energy storage. They also consult and design solutions for energy-efficient buildings, island networks, smaller and independent auxiliary power system, public transport and electric mobility applications.

Although Siemens maintains facilities in Beijing, Shanghai, and Nanjing, their marketing focus for energy storage products and system seems more keen on other global markets in Europe, and most specifically, Brazil.

Major customers include Enel and Dong Energy.

ALSTOM: Alstom believes pumped-storage hydroelectricity is the only economical and flexible way of storing large amounts of energy. They are the world leader of pumped-storage plants in operation around the world, having captured an average of 47% of the pumped-storage market share per year since 2004. Their pumped-storage equipment includes pump turbines, motor generators, and variable speed motor generation.

With 50 years of history, Alstom has a large presence in China. The grid sector employs over 1,800 people, has set up 10 industrial sites, an R&D center, and a number of offices across the country, bringing the total number of Alstom employees to more than 10,000 working in 30 different sites.

Alstom has 3 pumped-storage plants in China in the provinces of Huizhou, Baoquan, and Bailianho. They are also involved in other large hydro-turbine projects, including Three Gorges, Guanyinyan, Liyuan and Xianjiaba, the latter of which is the world's largest to date.

They are currently engaged in multiple partnerships in order to secure the scale-up of Carbon Capture and Storage Technologies and are currently investigating how to set up CCS demo plants in China.

In June of 2012, Alstom Grid and the teams of the French state owned research entity CEA-INES, announced the creation of a joint R&D Center in Chambery, France. The focus of the venture is to accelerate the deployment of embedded storage into Smart Grid systems and to develop advanced energy storage solutions to integrate renewable energy farms into smart transmission and distribution grids.

SCHNEIDER ELECTRIC: Schneider Electric provides consultation, products and services for the following Smart Grid solutions: Smart Medium Voltage (MV)/Low Voltage (LV) equipment, Substation Automation (including communication elements, such as ethernet switches, engineering tools, controllers and RTUs, digital control systems, GUIs, SCADA and EMS gateways and simulation tools), Feeder Automation, Enhanced Distribution Management, Microgrid Control, Volt/VAR Management, Real-time Condition Monitoring and Electric Vehicle Load Management.

As it relates to electric utility companies, Schneider Electric provides solutions for power quality monitoring and analysis, small hydro power plant generation (<30MW), photovoltaic generation for solar farm and large buildings, and their EcoStruxture an integrated architecture to enable intelligent management solutions for customers who want to optimize energy efficiencies across multiple domains of their business.

Customers include AES Sole, Eneryo, Hidroelectrica, Solaire Direct-Vinon sur Verdon, and Service Energy-RioEngano's 20 MW project. In Asia, their customers include Sherritt International Corp./Sumitomo Corp./Korea Resources Corp.-Distribution Network and Solar Sailor (Hong Kong Jockey Club ferries).

In June of 2011, they acquired 74% of Delhi-based Luminous Technologies. Luminous makes inverters and power storage systems targeted to home users, as well as small to medium sized businesses.

In the same month of June 2011, Schneider Electric also acquired Telvent, an energy software provider. Telvent's software helps manage electricity grids and transportation systems serving industries like oil and gas with a strong position in North and South America.

S & C ELECTRIC: S & C is a leader at integrating energy storage into the grid. Their Pureware Storage Management System (SMS) can interface to all commercially available battery technologies, and their SMS currently connects more than 90% of the grid-scale sodium-sulfur batteries installed in the United States. The interface flexibility of this product enables usage for peak shaving/load management; load following; renewable generation smoothing and dispatch; islanding; frequency regulation/grid stabilization; facility power protection (UPS); and voltage/power factor regulation.

Their Purewave Community Energy Storage System (CES) is a smaller distributed energy storage unit connected to the secondary of transformers serving a few houses or small commercial loads. It has many of the same features of the SMS, including automatic islanding, VAR support, voltage regulation, and seamless return to normal.

S & C also has standalone software products called IntelliTeam that provide intelligence out to the grid to make automatic, real-time decisions crucial in applications such as power restoration and volt/VAR optimization.

Pure Players in the Energy Storage Market

A123 Systems: A123 provides advanced batteries and complete energy storage solutions for transportation, grid, and commercial products at the cell, module and system level. They manufacture next-generation lithium-ion battery technology called Nanophosphate EXT. It has an extreme temperature range capability for telecommunications backup of base transceiver stations, base station controllers and central offices. The technology also overcomes traditional military battery constraints for applications from military vehicles to microgrids to soldier power applications.

A123 provides lithium-ion battery systems for passenger and commercial EV, HEV, and PHEV customers. They have a plethora of customers in this industry including AI Te Power Train Technologies, BAE Systems, Daimler, Magna Steyr (systems integrator for Volvo), Navistar, Smith Electric Vehicles, Tata Motors, VIA Motors, Axeon, BMW, Delphi, Fisker Automotive, Geely and GM.

A123 has a megawatt-scale Grid Storage Solution (GSS) which helps integrate renewable power sources, such as wind and solar into the existing grid infrastructure. With more than 90 megawatts shipped to date, they are the world's leading suppliers of lithium-ion battery systems for grid energy storage for applications, such as frequency regulation, spinning reserve, renewable integration, and substation storage across power generation, transmission and distribution applications. Customers in this sector include Sempra Generation, Southern California Edison, Dongfang Electric Corporation, Vestas, Maui Electric and the UK's Northern Powergrid.

The company is also involved in datacenter UPSs, IT backup, industrial robotics, autonomously guided vehicles (AGVs) and medical systems.

A123 is extremely involved in the Asian work space. They have a location in Korea and 2 in the Chinese provinces of Shanghai and Changzhou. On July 20, 2012, the company announced they will supply a 2 MW grid energy storage system to Ray Power Systems Company, LTD, a Chinese company focused on developing the frequency regulation market and relevant technology, particularly in Northern China.

They are also expanding their partnership with SAIC Motor Corporation, LTD, the largest automaker in China. They are conducting a feasibility study to define the business plan and required investment for a jointly developed battery manufacturing facility in China with initial focus on transportation.

In India, A123 is supplying lithium-ion battery packs to Tata Motors, the country's largest automaker, for their hybrid electric systems for commercial vehicle applications. Their scalable battery packs can fit into multiple power train architectures.

Xtreme Power: As a result of more than two decades of research, XP's "Power Cell" has furthered the cause of innovative battery technology. The Power Cell is a 12 volt, 1kWh, dry cell technology. Metal alloy-coated, ballistic grade fibers are woven together to offer structural integrity, as well as multiple pathways for ultra-low impedance current flow both in and out of the battery. Proprietary formulas of alloys such as copper, lead and tellurium are used to form bi-polar plates that provide a massive service area at the nano-scale for chemical reaction to take place. They are ideally suited for use in large-scale utility applications that require tens of megawatts power while still maintaining a manageable footprint.

Within the context of their Power Cells and high performance electronics, XP designs, engineers, manufactures and operates a fully integrated and digital energy storage and power management systems, called Dynamic Power Resources (DPR) for independent power producers, transmission and distribution utilities, and commercial and industrial end-users. It is a configurable control system that can be customized for integration into a large-scale, utility-ready system that operates with a customer's existing or planned infrastructure.

XP also provides a Real-Time Control System (RTCS) which allows DPR equipment to perform without the need for a full-time operator. It monitors the status of the conditions both internal and external to the DPR and allows users to remotely change settings in real-time. It is composed of three main components that together control the DPR equipment and record all the appropriate data:

- A web-based user interface for remote operation and monitoring which is integrated into the customer's existing control system or accessible through a Virtual Private Network (VPN).

- A SCADA system which communicates with remote terminal units (RTUs) and programmable logic controllers (PLCs) which collect readings from external sensors, meters, and breakers to relay data necessary for safe and accurate operation of the DPR.

- A data server which transfers and stores data in a secure database, which allows customers to access controls and permissions, interface with the XP GUI, and view graphical representations of historical and live operational data.

- In addition to integrating the above components, the RTCS also takes readings from any 3rd party SCADA, communication protocols, and voltage and current data in order to accurately provide the required system response of both real and reactive power.

XP's current client concentration is on wind projects in Hawaii.

ZBB Technologies: ZBB uses Zinc-Bromide batteries for energy storage, but also manufacturers flow battery technology believing optimal storage platforms may require a hybrid of technologies.

ZBB energy storage and power control platforms are used in grid interactive, grid independent, and grid conversion

environments for a variety of applications across global markets. They target the following applications:

- To deliver power to locations such as military operating positions reliant on diesel generators and/or unreliable grid power that might be security comprised.

- To provide power to cellular and communications towers reliant on diesel generators.

- To eliminate or minimize the use of diesel generators in commercial buildings for back-up power requirements.

- To provide EV charging stations the ability to charge vehicles without disruption to the Grid.

- To deploy power to disaster sites that rely solely on generators and/or unreliable grid power in emergency situations.

- Micro-Grids.

The ZBB EnerSystem is the world's only integrated management platform that's configurable, modular, flexible and scalable for on-grid and off-grid and back-up power applications. It combines advanced power and energy controls with energy storage that supports renewable energy sources and other power inputs.

The ZBB EnerSection is a system platform that can be configured in a grid interactive, independent, or grid conversion platform to create a hybrid power conversion system.

The ZBB EnerStore flow batteries are ideal for distributed energy projects on or off the grid. EnerStore captures multiple value streams including time shifting, firming of renewables, load management, continuous power output and system backup. It's based on a 50kW module which incorporates all the hardware and software to operate as a complete energy storage system capable of being grid connected or as a stand-alone.

On July 25, 2012, ZBB announced a joint venture with Anhui Meineng Storage Energy System Company, LTD and the opening of an advanced manufacturing center in Wuhu, Anhui Province in China.

ZBB and Honam Petrochemical of Seoul, South Korea, the latter of which is one of the largest conglomerates in Korea and with operations throughout Asia, have just concluded the final milestone in a Joint Development Agreement which spanned from April 2011 to June 2012. They have extended the first phase of that agreement until September of 2012 and are currently discussing a manufacturing and joint market entry plan. Honam, a diversified producer of petrochemicals and advanced synthetic resins, has identified energy storage as a strategic priority business. They looked to ZBB for its Zinc-Bromide technology, which is recognized as the leading commercially available flow battery. In addition, Jeju Island has been designated as a small-scale test area for a $2.4 Billion Smart Grid project. In Korea's Smart Grid model, the distribution of electricity from the main power grid gives way to a micro-grid system where each home would have either a wind turbine of PV panels installed while being connected to the grid. ZBB's EnerSystem is seen by

Korea as a critical component of the Korean Smart Grid project.

Under the terms of the Honam-ZBB agreement and for $3 Million paid over a 4-quarter period, Honam gained non-exclusive rights to sell ZBB EnerStor product in Japan, Thailand, Taiwan, Malaysia, Vietnam and Singapore, as well as exclusive rights within Korea.

BYD: BYD, an Asian company, specializes in IT, automobile and new energy. They are the largest global supplier of rechargeable batteries and have the largest market share for Nickel-Caladium batteries, handset Lithium-ion batteries, cell phone chargers and keypads worldwide. Their IT Business Unit's customers included Nokia, Motorola, Samsung, Sony Ericsson, Kyocera and Phillips.

BYD Auto is the most innovative independent national automobile brand and leads the field of EVs with unique technologies.

In the field of new energy, BYD has developed products such as solar farms, battery energy storage systems, and EVs. In the solar industry, they provide solar modules (ranging from BYD water to PV module assemblies), inverters, Lithium-ion batteries, and LED lighting.

BYD has ambitious plans to reach 5 GW of module capacity by 2016, and it intends to start producing energy storage solution products on a mass scale by 2013. In addition, they are planning manufacturing facilities outside of China. The reason for the latter is their concern over the current US-China anti-dumping trade case. If the import duties end up being imposed, and the dispute moves to Europe, BYD believes the global market will shrink considerably and problems will be caused for Chinese companies, in particular. They are already planning a new module factory in Chennai, southern India with an initial capacity at 50 MW, but room to ramp up to 200MW. They also have a manufacturing facility in Hungary and a storage facility in Rotterdam, the Netherlands.

Until now, BYD has sold the majority of its modules (over 70%) to the European markets. However, their Asian and US markets are growing, and as such, in 2012 they forecast 50% to Europe with the remaining 50% to Asia (particularly China), Australia, and the US.

In January of 2012 it announced, with the State Grid Corporation of China, the launch of the world's largest battery energy storage station in Zhangbei, Hebel Province. BYD was chosen because of the company's non-phosphate battery technologies and its peak shaving and load leveling charge and discharge methodologies.
By 2013, BYD will also produce lithium batteries on a mass scale.

Toshiba: Toshiba has developed the SCiB battery (Super Charge Ion Battery), a high performance, long-life battery solution for a wide array of applications, ranging from EVs to electric bicycles and motorcycles, fork lifts/automated guide vehicles, HEV, PHEV and EV UPS's to grid storage applications for solar and wind power generation. It is expected that this technology can support Smart Grid systems for the next generation power supply and management solutions.

Toshiba is the primary contractor for a cutting-edge trial project in Japan to implement a fully functional Smart Grid on Miyako Island. They will also supply electrical gear for Okinawa Electric Power Company's trial of a localized project.

Chennai-based Toshiba Group Company has been awarded a contract to supply 2 units of 660 MV super-critical steam turbine and generator islands by Meja Urja Nigam. The equipment will be installed in the Meja Thermal Power Plant in Uttar Pradesh State. Setting up a local manufacturing facility and a phased manufacturing program with technology transfers in India was a mandatory requirement for the tender. Toshiba will own 75% of the facility, and it will be the first Toshiba-owned facility outside of Japan. Toshiba has set a target of $1 Billion in sales in FY 2015 for its thermal business in India.

In addition to Japan and India, the Toshiba Group will look to reinforce its presence in markets around the world, including Asia and the Middle East, where demand for thermal power plants is strong. Toshiba positions their thermal power equipment business as part of a comprehensive power generation portfolio alongside nuclear and hydropower.

Beacon Power: In 2009, Beacon Power received a loan guarantee from the United States Department of Energy (DOE) for $43 million to build a 20MW flywheel power plant in Stephentown, New York. On October 30, 2011, the company filed for bankruptcy protection under Chapter 11, Title 11, in the United States bankruptcy court in Delaware. As part of the bankruptcy court proceedings, Beacon Power agreed on November 18 to sell its Stephentown facility to repay the DOE loan. In February of 2012, Rockland Capital, a private equity firm, bought the plant and most of the company's other assets for $30.5 million. Rockland Capital intends to rehire most of staff and to provide the capital to build a second 20MW plant in Pennsylvania.

Beacon Power provides high-energy flywheel-based solutions for multiple utility grid-scale electric power applications such as fast response frequency regulation, closed mitigation for solar PV, ramp mitigation for wind/diesel/flywheel hybrid, stabilization of DG systems, peak power support, frequency response reserves, voltage support for rail systems, UPS, angular instability control, and reactive power support (VAR support) in multiple global markets.

Their Smart Energy 25 flywheel is a 4th-generation advanced energy storage solution designed to meet the requirements of demanding utility grid applications. It features a long-life, low-maintenance design, highly cyclic (charge-discharge) capability, and zero fuel consumption or CO_2 or other emissions. An array of Smart Energy flywheel units can be configured to form a Smart Energy Matrix plant, which can store and return megawatts of energy to maintain grid reliability and stability.

The storage systems are designed to help utilities match supply with varying demand by storing excess power in arrays of 2,800-pound (1,300 kg) flywheels at off-peak times for use during peak demand.

Boston-Power: Boston Power lays claim to a next generation Lithium-ion battery technology platform that can power applications ranging from EVs, BEVs, and PHEVs to utility-scale energy storage to portable electronics. The batteries are in mass production at their manufacturing facility in Asia.

Boston-Power has introduced two cell products, one of which is Swing Cells for transportation and stationary energy storage applications, as well as a family of battery blocks, modules, and systems for large format applications. Customers include BBABUS and Saab.

The Swing Rechargeable Energy Storage System (RESS) is the most advanced rechargeable energy storage system available in the transportation market today. They are ideal for government applications such as communications equipment, night-vision equipment, portable computers, unmanned robots, and GPS systems.

Boston-Power sees China as taking the lead in transportation and plans to focus in the near and long-term, as China represents the biggest market for clean technologies and energy storage products. With a $125 Million investment from private investors and the support of the Chinese government in the form of grants, low-interest loans, and financial and tax incentives, Boston-Power will build a Lithium-ion plant near Shanghai with the capacity of 400MW by the end of 2012. This will more than double Boston-Power's production capacity, a number equating to 20,000 passenger cars. Boston-Power also plans to add R & D and EV battery engineering facilities.

Boston-Power's strategy is to reallocate its global resources, including the movement of a number of positions and responsibilities to China.

Panasonic/Sanyo: Panasonic's Energy business includes HIT (Heterojunction with intrinsic thin-layer) photovoltaic modules, consumer rechargeable batteries, and batteries for HEVs, PHEVs, and EVs.

Sanyo's position in solar technology goes back to the 70's. Their rich history of product development has led to a special hybrid-type solar cell called HIT which offers superior performance in power generation, even in high temperatures. They are also the only manufacturer to make a bifacial solar panel called the HIT Double, which is able to convert energy from light both from the top and bottom sides of the panel.

They have developed a Smart Energy Storage System (SESS) which manages optimum control of charge and discharge of electricity from the grid or electricity generated by renewables and suitable for such application such as residential energy storage, community energy storage, substation energy storage and UPS.

Another product offering is an advanced energy storage system which uses 1.6kWh modules, each with 312 18650 lithium-ion cylindrical cells, the same that are used in laptops and automobiles. Modules are scalable to make a 1.6kWh system or a 1MW system operate as one single giant battery to provide support for renewables, emergency back-up supply, and to shift peak demand to help utilities manage their distribution networks.

Panasonic's goal to be the world's #1 green innovation company is on living display in the Kasau Energy Park. For Sanyo, now a subsidiary of Panasonic, the Green Energy Park is where energy storage, solar power and Smart Grid technologies will provide the next level of innovation and revenue streams. Technologies only dreamed about are now a reality, including a 1MW solar power system (enough to power 330 homes), a 1.5MW Lithium-ion mega battery system, and the latest in EV charging systems.

Ener1: Ener1 emerged from a bankruptcy proceeding in March of 2012 thanks to a Russian rescue. The rescue has resulted in the company's technology being owned outright by Boris Zingarevich, a Russian businessman with ties to Russian President Dimitry Medvedev, a fact that concerns technology experts in the US.

Ener1, and their subsidiary EnerDel, develop energy storage technology using Lithium-ion powered battery solutions for the transportation, utility grids, and industrial markets. They also develop commercial fuel cell products and nanotechnology based materials. Customers include Federal Grid Company, Portland General Electric, Toro, Lightning Motors, and Volvo. The company has manufacturing facilities in the US and Korea.

EnerDel has a 40% stake in a joint venture with Wanxiang Group, the largest tier-one automotive parts supplier in China, and its customers include SAIC, Changan, Haima, FAW, Dong Fang, Suzuki, and Yutong (the world's second-largest bus maker), and Hangzhou State Grid. EnerDel is also the second-largest stakeholder in Guangzhou Automobile, China's most profitable domestic car company, which also has joint venture partnerships with Honda, Toyota and Fiat. The joint venture recently received its business license by the Chinese government to design, manufacture, sell, distribute and provide service for Lithium-ion battery cells and packs for transportation and grid energy storage sections in China.

Vycon: Vycon is a manufacturer of technologically advanced flywheel energy storage systems. They specifically serve the UPS industry by eliminating or supplementing lead-acid batteries. Vycon's systems also result in reduced peak power, lower fuel consumption, and energy saving in electric motors and diesel generators on shipyard cranes, rail power substations and wind power generation systems.

The flywheel-based energy storage systems hold kinetic energy in a spinning mass, and convert this energy to electric power through the use of a high speed electric motor or generator.

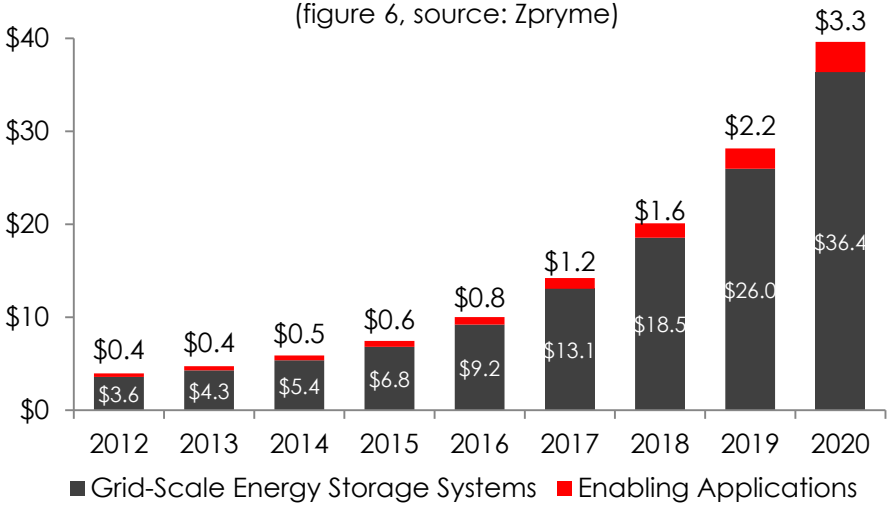
Configuration for their VDC and VDC-XE products support critical power markets such as data centers, healthcare facilities, mobile power, industrial plants, casinos and others as a DC source for UPS systems. The same flywheel can be repackaged for section power in rails, as well as wind and power, and Smart Grid Storage.

Customers include Emerson Network Power, Eaton Corporation, EMC, JV Industrial, Actavis, Gambro, EasyStreet, WDIQ, Virtua Data Center and Austin Energy.

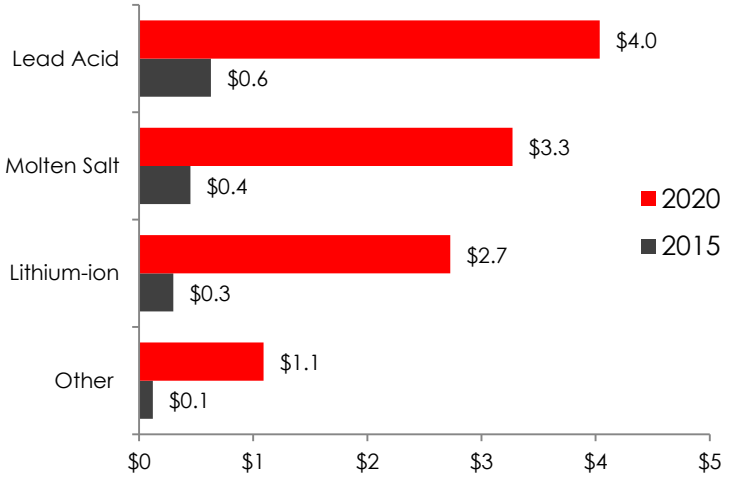
In May of 2011, Vycon opened a representative office in Singapore to support current and prospective customers in Asia and Southeast Asia.

Asia: Energy Storage Opportunity

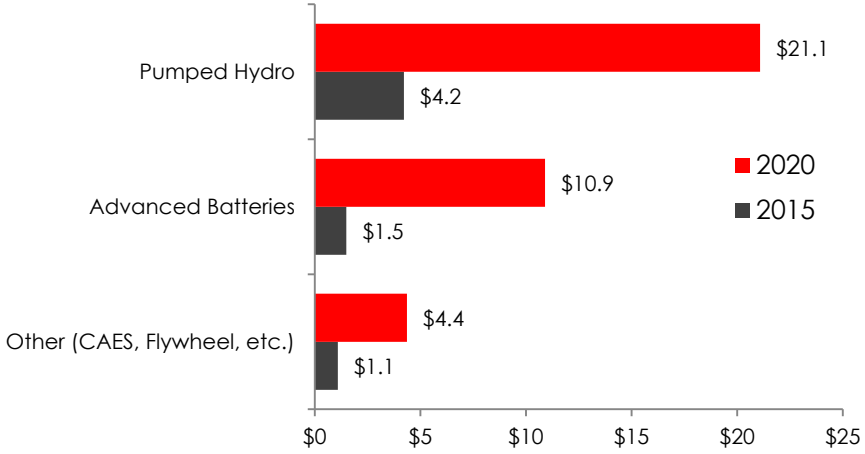
Asia Energy Storage Systems and Applicaitons Market Value Forecast
2012 to 2020 (in US billions)
(figure 6, source: Zpryme)



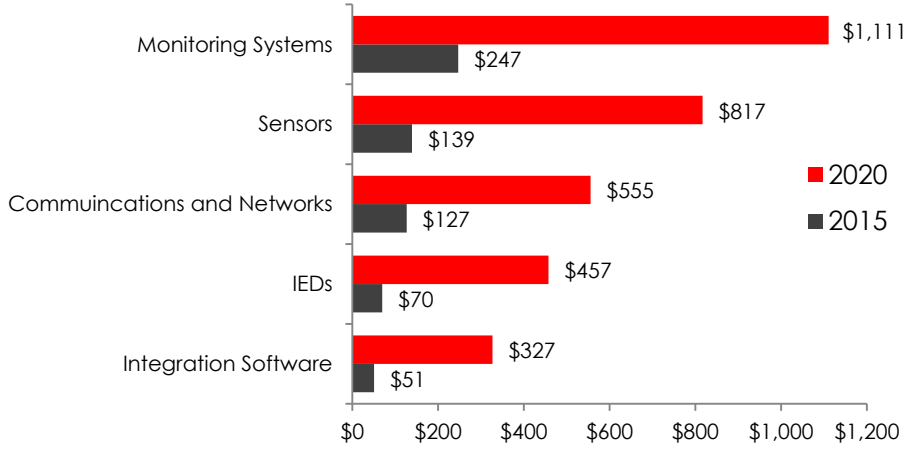
Asia Grid-Scale Energy Storage Systems Market Forecast by Battery Type
2015 and 2020 (in US billions)
(figure 8, source: Zpryme)



Asia Grid-Scale Energy Storage Systems Market Forecast by Technology
2015 and 2020 (in US billions)
(figure 7, source: Zpryme)



Asia Applications for Grid-Scale Energy Storage Market Forecast by Technology
2015 and 2020 (in US millions)
(figure 9, source: Zpryme)



Asia: Market Drivers

Asian countries are the top consumers of clean energy in the world, and as such, they are also expected to dominate in the provision of clean energy products.[24] Asia Pacific is expected to account for two-thirds of global energy demand growth by 2030, according to industry experts,[25] and China's drive for power generation is starting to affect the regional economies and suppliers around China. With a large domestic base of R&D and manufacturing for battery technologies, the technical diversity of energy storage projects in Asia Pacific is rather wide. Factors driving the demand in the Asian energy storage market include rising energy demand, the requirement for grid stability, government funding and incentives, an increasing focus on renewable energy sources, the R&D and manufacturing of energy storage systems, the use of energy storage technologies across multiple sectors, and the falling prices of energy storage technologies.

It is anticipated that the global demand for electricity will rise for at least the next two decades, and renewable energy sources are expected to supply a much higher percentage of total generating capacity. As a result, utilities are making huge investments in developing innovative electricity storage systems for large-scale applications.

Southeast Asia's rapidly expanding population, and the subsequent growth in the demand for power, has resulted in the substantial development of electrical infrastructures, including power grids. Congruently, the need to store energy from clean and renewable sources, such as wind and solar, for utility and smaller scale applications has become a major priority and is driving innovation in the field.[26]

Advanced electric energy storage systems will be an essential part of the future development and transformation of a range of applications, including renewable energy, grid stabilization, back-up power, and portable devices. In addition, the transportation industry stands to profit from the replacement of lead-acid batteries with lithium batteries for industrial equipment such as forklifts, utility vehicles, golf carts, and UPS systems.

In terms of revenue, the Asian region claims the lead in the battery manufacturing market with products ranging from lead-acid, NiMH, NiCd, and lithium ion. This is primarily due to the high production of batteries in the region by companies such as Panasonic Corporation (Japan), BYD Motor Co. Ltd. (China), Sanyo Electric Co. Ltd. (Japan), Hitachi Ltd. (Japan), GS Yuasa Corporation (Japan), and Furukawa Electric Co. Ltd. (Japan).[27]

Japan has made huge investments in the R&D of large capacity energy storage technology since the 1990s. In 2009, nearly 90% of energy storage projects were being conducted in Japan.[28]

Government funding and subsidies are also boosting the energy storage market in Asian Countries. For example, the Shenzhen government has highlighted the

[24] Green Prospects Asia
[25] PESA
[26] BCC Research
[27] Reuters
[28] SINOMORE investment Management Company

development of an energy storage power station as its top priority. In India, the Ministry of New and Renewable Energy (MNRE) is supporting the development of long life storage batteries suitable for use in PV systems and the development of new storage systems up to MW scale.[29]

According to industry experts, innovations in storage technologies will lead to falling prices of energy storage solutions that consumers and municipal utilities will be able to take advantage of.[30] Declining prices and the increasing demand for lithium-ion batteries from electric and hybrid vehicle manufacturers, as well as the growing demand in the energy storage industry, have positioned lithium-ion to displace lead acid as the leading battery technology.

Major Technologies To Be Deployed

The major applications for energy storage in Asia will be frequency regulation, load following, spinning reserves, and short-duration renewables integration. The primary technologies for these energy storage services will include flywheels, pumped hydro storage, compressed air energy storage (CAES), and battery technologies, such as lithium-ion, sodium sulfur and advanced lead-acid batteries.[31] Advanced batteries are set to attract the greatest interest in the near future. This is because of their flexibility in use, allowing for their employment in grid balancing and connecting intermittent renewable energy generators to the main electric grid. Further, over the next five to seven years, lithium-ion batteries will play the most important role in the future of electric energy storage systems. Electric vehicles (EVs) will be a key and sizeable application area for this technology.

- Advanced adiabatic CAES systems are anticipated to play a significant role in enabling the safe connection of big wind farms to the main electric grid in an economically viable way. Nevertheless, all of these systems are still either at the developmental stage (advanced batteries) or are not yet mature (CAES). Currently, the only available and economically viable storage system is pumped hydro, whose use is significantly limited because of the need for proximity to large water reservoirs.

- Bulk energy storage technologies such as pumped hydro will play an increasingly important role in emerging markets such as China.[32]

- The largest manufacturer of sodium sulfur batteries is Japan's NGK Insulators, LTD. They have been the global leader in grid-scale storage for over a decade with an installed base of over 300 MW. In 2011, NGK accounted for roughly 54% of the grid-scale energy storage market.

- There have been no publicly held companies in the vanadium redox flow battery space since China's Prudent Energy bought VRB Power Systems in January 2009. In 2012, US-based ZBB Energy Corporation emerged as the only publicly held company to become engaged in the zinc bromine flow battery space. ZBB is actively exploring markets for zinc bromine flow batteries, as well as agnostic control

[29] MNRE
[30] SolarPrices.Org
[31] Electrical Contractor
[32] Pike Research

systems that can integrate and manage a variety of conventional and renewable power sources and energy storage technologies.[33]

- In the next 10 years, the lithium-ion battery industry is expected to be driven by demand from the residential and electric vehicle markets.[34]

- As of 2011, China is the world's largest lead-acid battery producer and exporter. They supply about one-third of global total needs.

China

According to a study by the US Energy Information Administration, China's electric grid will become the largest in the world in terms of both installed generation capacity and electricity produced in 2012. China also has the world's largest installed wind power base and the world's largest declared investment in renewable energy. This makes China the most attractive market for energy storage in the world, especially since China currently has only 4% of the worldwide energy storage capacity.

While other markets have focused on power quality and ancillary services, China's grid energy storage market has developed with a focus on renewable energy integration, load-shifting, and peak shaving. One of the key factors contributing to this market growth is the increasing number of e-bike manufacturers.[35] In 2011, it was announced that Beijing plans to invest $1.7 trillion in "strategic sectors" (including alternative energy) over the next five years. According to CEO Luka Erceg of the US-based sustainable materials technology company, Simbol Materials, this builds on the $500 billion in Chinese public and private investment in lithium production since 2000.[36]

Government Funding for Energy Storage Projects

China's State Grid Corporation announced in 2011 that it would invest $250 billion in electric power infrastructure upgrades over the next five years, which will include a $45 billion investment in Smart Grid technology.[37] China has no comprehensive policy relating to energy storage. However, multiple municipalities have implemented policies to encourage local development and deployment of energy storage technologies.

The national government has also allocated resources to numerous demonstration projects as part of the 12th Five-Year Plan (2011-2015) for Smart Grid development.[38] For example, in 2012, the Shanghai Municipal Government announced that it will invest about $2.83 billion (CN¥18 billion) in the new-energy industry during this 12th five-year plan.[39] The energy storage industry is a key focus area of the 12th plan on Smart Grid development projects.[40] The government has also earmarked $1.5 billion annually for its electric vehicles industry for the next 10 years.[41]

[33] RenewableEnergyWorld.com
[34] InvestorIdeas.com
[35] TransWorldNews

[36] U.S. House of Representatives
[37] American Progress.Org
[38] University of California
[39] China Energy Sector
[40] SGT Research
[41] Facts and Detail

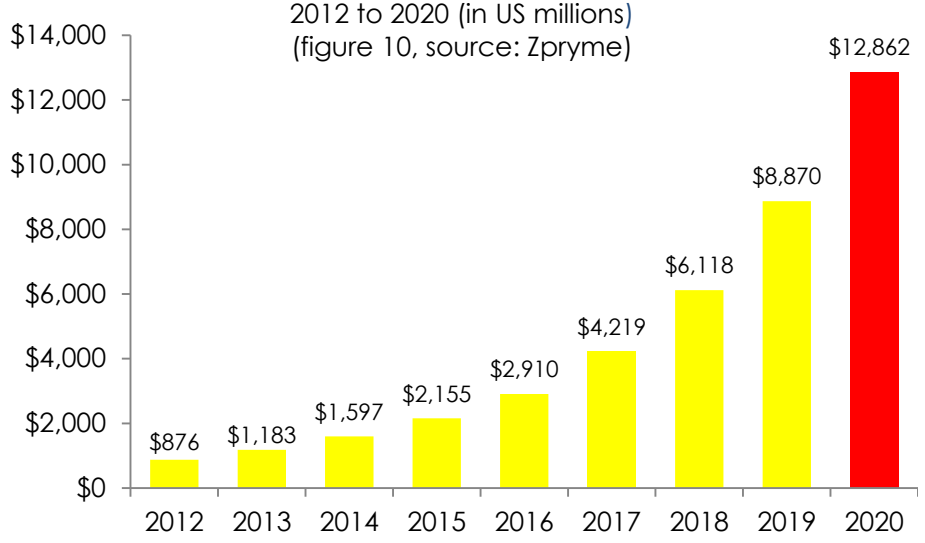
Storage Technologies Funded

The Shenzhen government has set up the "Support Program on Energy Storage Pilot Project", and provides monetary support for the same. The Shanghai government has also given electric power storage top priority for the development of the Shanghai Smart Grid industry. Moreover, the government is focusing on accelerating the development of electric power storage technologies such as flow and lithium-ion batteries, as well as developing distributed energy storage technologies. The Jiangsu government is concentrating on the R&D of Smart Grid energy storage devices such as EV batteries, CAESs, Flywheel, and super capacitors. Hunan is focusing on developing micro-off-grid wind power stations using storage batteries. Gansu supports the R&D and industrialization of nickel-hydrogen and lithium-ion battery projects.[42]

Market Forecast

From 2012 to 2020, the China market is projected to grow from $876 million to approximately $12.9 billion with a compound annual growth rate of 40%.

China Grid-Scale Energy Storage Systems
Market Value Forecast
CAGR = 40%
2012 to 2020 (in US millions)
(figure 10, source: Zpryme)



Major Energy Storage Projects/Demonstrations

- The Shanghai World Expo features a 100 kW NaS system sponsored by the Shanghai Municipal Electric Power Company, the Shanghai Institute of Ceramics and the Chinese Academy of Sciences.[43]

- The China Southern Power Grid and the Chinese automaker, BYD, have set up a 10 MW lithium-ion demonstration called the Shenzhen Baoqing Battery Energy Storage Station.[44] In 2012, BYD also collaborated with the State Grid Corporation of China (SGCC) to construct a battery energy storage station in Zhangbei,

[42] SINOMORE Investment Management Co., Ltd.

[43] CGTI
[44] Green Prospects Asia

Hebei Province. The project is estimated at $500 million.[45]

- The China Electric Power Research Institute, Prudent Energy and SGCC have won approval for a 7.5 MW vanadium redox battery (VRB) system in Zhangbei, Hebei.

- In 2012, China BAK Battery, Inc. received a $1.9 million subsidy for a battery module project from the National Development and Reform Commission and Ministry of Industry and Information Technology.[46]

- In 2011 Prudent Energy finalized the installation of a 1MWh Vanadium Redox Battery Energy Storage System at a wind and solar test center project in Zhangbei, China.[47]

Japan

Since the Fukushima nuclear power plant disaster, there has been a pressing need in Japan to address electricity supply instability, while striving to realize a low-carbon society through the use of renewable energy. This requires implementing energy demand peak-time cuts and peak-time shifts through on-site energy creation and energy storage to stabilize energy demand, as well as to promote the increasingly popular concept of local energy self-sufficiency. According to EnergyTrend, energy storage systems will first be adopted in local emergency assistance systems, such as large standby power systems. The systems are expected to make their way into households to help reduce energy consumption during peak hours, and in turn, lower the need for nuclear energy. EnergyTrend expects the demand for energy storage systems to surge considerably in 2012.[48] Japan is also seeking foreign markets for its technology. The New Energy and Industrial Technology Development Organization (NEDO) consortium is one of several partnerships pushing Japanese technology to foreign markets. In the US, Hitachi has a lead role in a DOE-funded Smart Grid demonstration in Hawaii.

Government Funding for Energy Storage Projects

In addition to enhancing their competitiveness,[49] the energy storage plan put forth by the Minister of Economy, Trade and Industry includes developing and installing large storage batteries for the electric power industry, increasing reliance on renewable energy, disseminating stationary storage batteries as backup power for blackouts, and developing automobile batteries The government's budget for R&D projects that are focused on storage battery technologies rose from about $94.09 million (¥7.48 billion) in FY 2011 to $119.51million (¥9.5 billion) in FY 2012.[50]

The latest green energy policy implemented by the Japanese government in March 2012 provides subsidies for residential energy storage systems which are presumed to be a $0.76 billion (¥60 billion) market. This segment of the storage market is expected to grow to about $250 billion (¥20 trillion) by 2020. According to a report from the Ministry of Economy, Trade and Industry, Japan could take

[45] Business Wire
[46] Global Renewable News
[47] SolarServer
[48] EnergyTrend
[49] METI
[50] METI 1

50% of the market, up from 18% of its share of the $66.16 billion (5.2 trillion yen) market in 2011.

Storage Technologies Funded

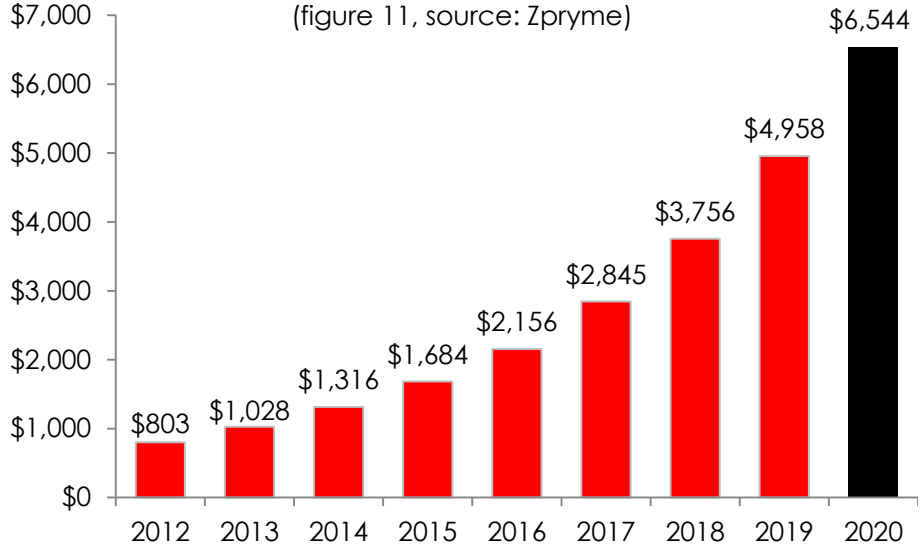
Since the 1970s, Japan has invested heavily in the R&D of battery technology and has supported projects pertaining to lead-acid batteries, flow batteries, sodium sulfur batteries, lithium-ion batteries, and Ni-hydrogen batteries. Since the 1990s, Japan has also made huge investments in the R&D of large-capacity energy storage technology. In 2009, nearly 90% of energy storage projects were in Japan. Domestic investments are estimated to reach 5 trillion yen by 2020.[51]

The Japanese government has introduced a three-year subsidy program, worth $264.18 million (¥21 billion), for use of stationary lithium-ion battery energy storage systems starting in FY 2011.[52] The government is also planning to introduce R&D projects focused on lithium air batteries to significantly improve electricity storage density. The New Energy and Industrial Technology Development Organization, a public management organization promoting industrial, energy and environmental technologies in Japan, also invests in R&D projects for the energy storage industry.[53]

Market Forecast

From 2012 to 2020, the Japanese energy storage systems market is projected to grow from $803 million to approximately $6.5 billion, with a compound annual growth rate of 30%.

Japan Grid-Scale Energy Storage Systems
Market Value Forecast
CAGR = 30%
2012 to 2020 (in US millions)
(figure 11, source: Zpryme)



Major Energy Storage Projects/Demonstrations

- Panasonic Corporation is installing solar power generation systems and home-use storage battery systems across the "Fujisawa Sustainable Smart Town", including residences, various facilities and public

[51] SINOMORE investment Management Company
[52] Jetro
[53] NEDO

zones.[54] The estimated project cost is about $768.06 million (¥60 billion).

- Toshiba is developing a "smart community" in Ibaraki, Osaka, Japan. Electricity storage devices will be installed and rechargers for electric vehicles will also be set up for the project.[55]

- Nippon Electric Company is developing an Energy Management System using lithium-ion batteries for the Yokohama Smart City Project, a five-year pilot program that started in 2011.[56]

- Hitachi is working on integrating home energy and community energy management systems in several Smart Grid projects such as the project in Rokkasho, Aomori Prefecture in Japan.[57]

- Mitsubishi is working on a series of Smart Grid projects in Japan. In 2011, Mitsubishi Heavy Industries, Ltd., (MHI) delivered a large-capacity energy storage system employing lithium-ion rechargeable batteries to the Shimizu Institute of Technology in Tokyo.[58]

- NGK Insulators develops sodium-sulfur batteries in cooperation with Tokyo Electric Power Co., Ltd. Japan has installed approximately 250 megawatts of NGK's sodium sulfur batteries.[59]

[54] Panasonic Corporation
[55] The Asahi Shimbun Company
[56] Nippon Electric Company, Limited
[57] Hitachi
[58] Mitsubishi Heavy Industries Limited
[59] Greentech Media, Inc.

- Kawasaki has introduced a railway wayside energy storage system, called the Battery Power System that is directly connected to a 1,500 VDC traction power line. The BPS uses Kawasaki's proprietary large-scale GIGACELL Nickel-Metal Hydride Battery.[60]

- Toyota is planning to build 67 solar-powered model homes that manage electricity consumption and tap into weather forecasts, using battery units provided by Denso Corporation.[61]

South Korea

Power consumption in South Korea rose dramatically in 2011. One of the major causes of the increase in power use is the rise in consumption of electricity by households and buildings for air conditioning.[62] Furthermore, South Korea's renewable energy capacity grew by 88% from 2005 to 2010, according to an energy finance report by Bloomberg. In addition to becoming a net exporter of clean energy, South Korea expects to earn its place among the top five countries in the renewable energy sector energy by 2015. Energy storage technologies including fuel cells are also expected to gain increased interest.[63]

Government Funding for Energy Storage Projects

According to the Ministry of Knowledge Economy (MKE), in 2012 South Korea will invest about $1 billion into the research and development of renewable energy sources

[60] KHI
[61] Greentech Media
[62] Energy Daily
[63] Green Prospects Asia

such as solar power, offshore wind power, photovoltaic cells and fuel cells, among others. The investments will go to 19 energy projects divided into four divisions: the development of energy resources, renewable energy development, nuclear power generation, and radioactive waste treatment. The Ministry also plans to help local companies develop future technologies that cover energy storage, solar power and wind power.[64]

Storage Technologies Funded

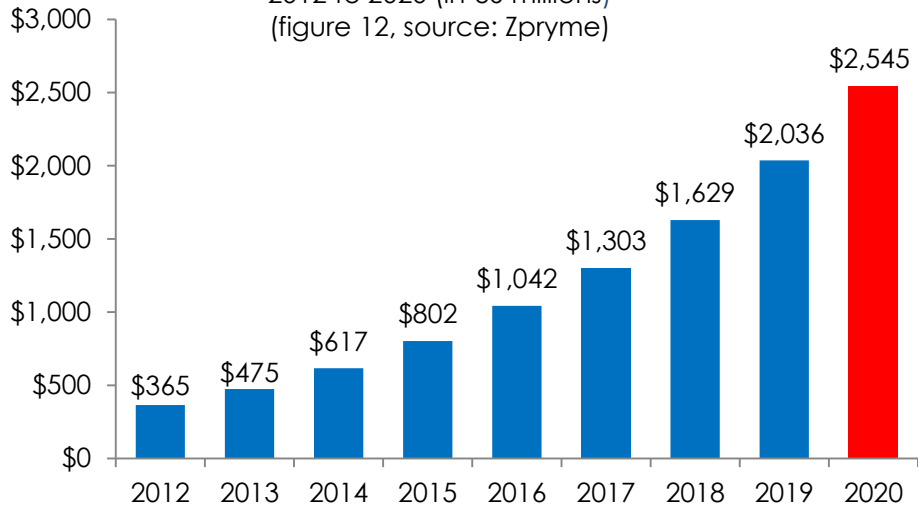
In 2011, the MKE announced that South Korea will invest approximately $5.92 billion (₩6.4 trillion) by 2020 to promote the energy storage system industry. According to the MKE, about $1.70 billion (₩2 trillion) will be set aside for promoting technology development and the remainder will be used for the build-up of necessary infrastructure. The MKE will select and promote four technologies that can develop megawatt-class energy storage systems in three years or can be used for industrial purposes in five years.

Lithium-ion batteries, NaS batteries, redox flow batteries, super capacitors, fly wheel energy storage and compressed air storage technology may be the candidates for the project. In 2010, the MKE released a preliminary long-term energy plan to nearly double its production of lithium in the next year.[65] In 2011, it was announced that the South Korean government will support lithium production with $300 billion in subsidies.[66] Moreover, under the Electric Vehicle Industry Promotion Plan, the government plans to invest about $339.6 million (₩400 billion) in a R&D program focused on core automobile components through 2014, of which $46.80 million (₩55 billion) will be spent on the development of high-performance, medium-performance, and large-sized secondary batteries for automobiles.[67] The government is also considering providing additional subsidies and tax breaks for electric-car makers and buyers.

Market Forecast

From 2012 to 2020, South Korea's market is projected to grow from $365 million to $2.5 billion, with a CAGR of 27%.

South Korea Grid-Scale Energy Storage Systems
Market Value Forecast
CAGR = 27%
2012 to 2020 (in US millions)
(figure 12, source: Zpryme)



[64] Asian Power
[65] Ep Overviews
[66] Smart Grid Today

[67] Bloomberg

Major Energy Storage Projects/Demonstrations

- In 2009, KEPCO initiated one of the largest Smart Grid test projects in the world on Jeju Island in South Korea. Representing an estimated investment of $200 million ($50 million from public funding, and $150 million from private investment) for the period 2009-2013, ZBB and its partner, Honam Petrochemical, are providing the EnerStore zinc-bromide flow battery technology that will be used as an advanced electrical energy storage device at the site.[68]

- The South Korean government is planning to build an 8 MW energy storage facility at a substation in Jocheon, Jeju Island by 2014.[69]

- Samsung Group is planning to invest $7.01 billion to build a green energy industrial park producing wind power generators, solar batteries, and energy storage systems.[70]

- In 2010, POSCO, a steel-maker in Korea, developed a sodium sulfur (NaS) battery for large capacity energy storage and is planning to commercialize it by 2015.[71]

- The Korean Rail Research Institute has collaborated with Kinetic Traction Systems, Inc. (KTSi) for the installation of two flywheel units for trackside energy storage and recycling.[72]

[68] JSOnline
[69] Platts
[70] Eco-Business
[71] POSCO
[72] On Green

- LG Chem in 2011 completed a battery plant for electric cars in Ochang, south of Seoul. The plant has capacity to produce lithium-ion batteries for 100,000 green autos per year.[73]

- SK Energy is supplying lithium-ion batteries for a hybrid electric vehicle project for 90 Mitsubishi Fuso and for Hyundai Motor and Kia Motors EVs.[74]

India

Utility-scale solar plants – both PV and solar thermal – are suddenly being taken much more seriously, largely in part as a result of the recent problems within the nuclear industry. Large solar plants inevitably require large energy storage systems with energy density requirements that most of today's commercialized storage systems do not currently offer.

Small lead-acid batteries have been used in India for many years in off-grid photovoltaic (PV) systems, and are poised to remain an important part of "solar storage" in the Indian market. However, recent developments in energy storage have created significant new revenue opportunities for India. India has a large number of villages that do not have electricity. Because of the tremendous expense that would be required to extend the transmission of power to these village, those that are electrified in the near future will require micro-grids, most likely tens of thousands of them. These micro-grids require much larger energy storage systems than the traditional batteries used for off-grid applications. Thus, there will be a considerable

[73] AFP
[74] EV Driven

need for flow batteries to provide adequate storage capacity. As metering technology advances in urban India, the introduction of energy storage by building owners will give them the ability to take advantage of the best feed-in-tariffs. However, this landscape is currently waiting for specialized types of energy storage systems to emerge.[75]

Government Funding for Energy Storage Projects

The Ministry of New and Renewable Energy (MNRE) identified thrust areas for R&D in the 11th five-year plan (2007-2012). These include solar photovoltaic energy, wind energy, pumped-hydro energy, fuel cells, hybrid vehicles, and battery operated energy storage systems. Under the plan, the MNRE has proposed an investment of about $71.20 million for R&D activities related to energy storage systems.[76] The plan focuses on the development of long life (5000 cycles or more) storage batteries suitable for use in PV systems/applications. The plan also emphasizes the development and testing of new storage systems up to megawatt scale.[77]

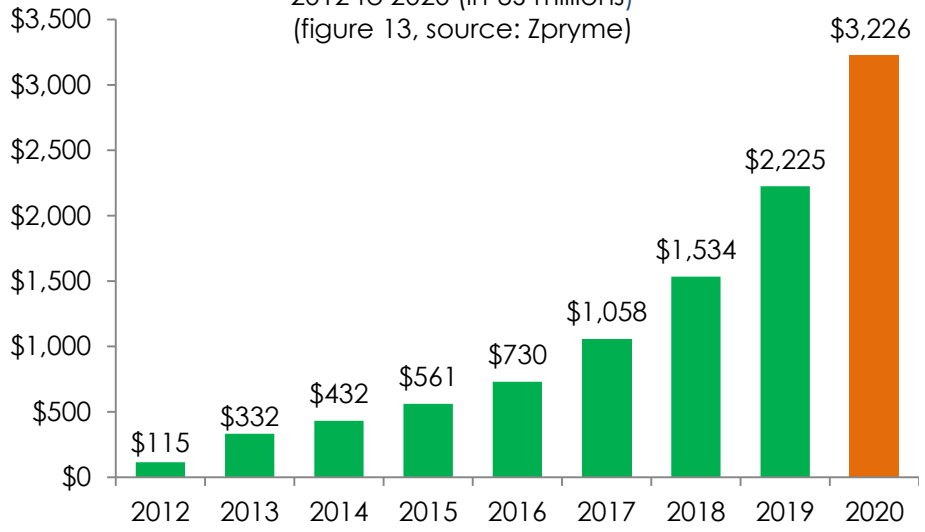
Storage Technologies Funded

In India, stand-alone solar energy systems mainly operate with the use of lead-acid batteries. However, with low power consuming LED based systems; the use of NiMH batteries is advancing. The 11th five-year plan focuses on enhancing battery operating life to at least 10 years. The government is also urging emphasis on developing non-lead acid batteries. Capacitors are also being used to store energy, especially in fuel cell vehicles. The MNRE is also focusing a good portion of their R&D efforts on the development of improved storage technologies, including those that utilize super conducting bearing-based fly wheels.[78] The MNRE provided $7.12 million during 2010-2011 for the implementation of technologies which include chemical sources of energy, hydrogen energy, geothermal energy, ocean energy, and alternate fuels for surface transportation.[79]

Market Forecast

From 2012 to 2020, India's market is projected to grow from $115 million to $3.2 billion, with a compound annual growth rate of 52%.

India Grid-Scale Energy Storage Systems
Market Value Forecast
CAGR = 52%
2012 to 2020 (in US millions)
(figure 13, source: Zpryme)



[75] EAI
[76] Planning Commission
[77] MNRE
[78] MNRE 1
[79] MNRE 2

Major Energy Storage Projects/Demonstrations

- The Delhi-Mumbai Industrial Corridor (DMIC) Project in India is a $90-billion Indian government initiative. To be implemented in collaboration with Japan, the JGC Corporation will build a next-generation electricity distribution network utilizing its storage battery technology in Shendra, east of Mumbai.[80]

- Tata Group and Mitsubishi Heavy Industries (MHI) Ltd. have also collaborated to jointly conduct a feasibility study for the creation of a smart community. The study includes lithium-ion battery applications for electric vehicles, an energy storage system, and energy for power generation.[81]

- The SunCarrier Omega Net-Zero Energy Building in Bhopal, Madhya Pradesh, is an off-grid solar powered facility. Energy generated by the sun-tracking SunCarrier solar PV systems feeds the lighting and air-conditioning load for the building, while also charging the large capacity Cellcube vanadium redox flow battery and energy management system.[82]

- The Purulia Pumped Storage Project of West Bengal State Electricity Distribution Company Ltd. (WBSEDCL) can generate 900 MW power instantly by discharging stored water from the Upper dam to the Lower Dam through a reversible pump-turbine and generator motor. The project was commissioned in 2008 at a cost of $526.07 million.[83]

- In 2012, it was announced that A123, a US-based battery company will produce battery packs for hybrid-electric buses made by Tata Motors.[84]

[80] The Economic Times
[81] MHI
[82] India PRwire
[83] Construction Update

[84] Ev-olution.org

5 Keys to Entering Asia's Energy Storage Market

1. The four countries profiled in this report are the major Smart Grid drivers in Asia, but each has a distinct set of dynamics across many layers – economic, social, political, cultural, etc. All are attractive, but success will require a specific market entry strategy for each one. As with other sectors, energy storage vendors should seek to establish local partners or leverage existing partners in the region.

2. Asian economies are less open than the West, and government agencies play an even greater role here, especially for strategic sectors like energy. Smart Grid and renewable energy have great value in Asia, not just economically, but politically as a means to showcase their progress on a global stage. Market entry for energy storage should include an active component for partnering with government agencies and educational facilities for pilot studies, demonstration projects, R&D programs, etc.

3. Mid-tier and smaller markets such as Vietnam, Malaysia, and the Philippines also hold great promise. These markets may not be as saturated with Smart Grid players as their larger Asian counterparts, and their governments likely need more technical guidance on the implementation of energy storage and other Smart Grid technologies. For vendors who lack the scale or footprint to break into the larger Asian markets, this may be the best route to success.

4. Energy storage is a global opportunity and Asia thinks globally. For vendors new to this market, we recommend either partnering or establishing relationships with global players who have deep roots in Asia, such as Siemens, ABB, IBM, Accenture, and GE. If the technology proves viable and can scale, these companies could help niche firms enter the market either directly or integrated with their solutions.

5. For a variety of reasons addressed in this report, Asian countries are world leaders in Smart Grid, and they already recognize the value of energy storage. They will adopt energy storage technologies faster, more boldly and on a greater scale than other markets, and vendors need to be aligned with this thinking. Innovation and speed to market matter more here than cost, as Asia struggles to catch-up to exploding demand for energy. Energy storage vendors may have some early success addressing simple problems or being the low cost leader, but to be a long term player, the value proposition must speak to the bigger picture regarding how Asian utilities need to operate today.

Zpryme's Market Outlook, 2012 - 2020

Over the next five to eight years, the energy storage market will go through the typical economic cycles of new entrants, bankruptcies, acquisitions and consolidation. The market is not yet mature enough to support many firms offering various types of technologies, as the R&D process is long and costly, and demand remains in an early stage. By 2020 we anticipate a handful of global firms will dominate this market, as they will likely purchase existing pure players with the most advanced technology and incorporate them into their large scale solutions.

We expect that Asian-based manufacturers will initially take the lion's share of the Asia energy storage market, but international firms with advanced energy storage systems have a strong chance of success, especially if they can provide utilities and end-users with significant cost advantages over the technologies provided by Asian companies. That said, strong economic conditions in Asia as a whole will fuel innovation in advanced energy storage systems and applications, which will thus give Asian firms a competitive cost advantage over their North American and European counterparts.

Our research indicates an emerging opportunity for energy storage integrators who provide enabling applications, as well as for technology-agnostic energy storage system providers that offer flexibility and reliability over more proprietary solutions. As with communications technologies, Smart Grid will be built around open systems and interoperable elements. Until these systems become highly standardized, speed to market will require the expertise of integrators who can incorporate energy storage into the Smart Grid, and make renewable sources a more viable part of the energy mix.

Overall, we see both utilities and end-users being winners as energy storage technology contributes to a much more reliable and stable grid in Asian countries. Businesses will be more productive, hospitals will function more effectively, train service will be more reliable, more cars will run on batteries and households will benefit more from modern conveniences. Utilities will produce cleaner energy, higher quality energy, operate more efficiently and can reduce their dependency on fossil fuels. We expect all of this and more to materialize within our forecast period, and will update our thinking in a future report.

Q&A with:

Alcatel-Lucent | www.alcatel-lucent.com

ZP: Why are next-generation networks so critical to the overall success or advancement of the Smart Grid?

AL: A Smart Grid responds to the critical challenges facing utilities: rising global demand for electricity forcing utilities to improve efficiency, reduce waste and add new capacity; customers' expectations of increased control over their consumption; the integration of more renewable energy sources with their intermittent supply and remote locations. A Smart Grid is essential for providing the intelligence and control necessary to meet these challenges in a way that provides energy safely, reliably, securely and economically.

Next generation communications network are the key enabler of Smart Grids. A Smart Grid leverages information and communications technology (ICT) to interconnect and enable the flow of real-time information within the power utility, between the power utility and its suppliers and partners, and between the power utility and both its business and domestic customers. Smart Grids and their applications rely on a robust communications network that is secure, highly scalable and always available. Once operational communications was the preserve of the core energy network. Now the communications network must now reach out to the periphery of the Smart Grid and into every home and business. It must support the Smart Grid's potential to generate massive amounts of real-time data. And it must enable the distribution network to support monitoring and management of millions of devices in real time. As the enabler for Smart Grids, a next-generation communications network forms the basis for Smart Grid transformation and a revitalized power utility.

In light of this, many utility companies are upgrading their existing communication networks to Internet Protocol/Multiprotocol Layer Switching (IP/MPLS) technology. An IP/MPLS network, combined with the appropriate power sensors in the distribution network, allows power utilities to collect and reliably transport increased volumes of real-time usage data. With this visibility, power utilities can more accurately respond to rising or falling consumption. They can also dynamically adjust electricity supply to meet demand and better predict when and where there could be a weakness or a failure in the grid. In case of an outage, an IP/MPLS infrastructure enables Smart Grid applications to take immediate and automatic actions to limit the spread of the outage and to dispatch the right workers with the right tools and the right information to restore power as soon as possible. The carrier-grade characteristics of an IP/MPLS infrastructure — 99.999 percent

reliability, a fully deterministic behavior (including guaranteed latency), guaranteed Quality of Service (QoS) and full redundancy — also allow power utilities to safely and securely shift crucial Supervisory Control and Data Acquisition (SCADA) and teleprotection applications onto a common infrastructure as they gradually migrate to an all-IP network that supports both existing and new services.

ZP: How can Alcatel-Lucent's networking and communication solutions help utilities integrate storage into their respective electric systems?

AL: The intermittent production from renewable energy sources means that storage capabilities will be essential if utilities are to take full advantage of renewables such as wind and solar. With Smart Grid communication networks, utilities can monitor energy storage facilities, pinpoint sources of energy closest to demand and pull energy from those resources when needed. This will enable utilities to reduce their reliance on peaking plants and leverage greener sources of energy.

ZP: Which geographic markets offer the greatest potential for energy storage integration over the next five years?

JL: Storage is closely linked to renewables, therefore those markets investing more in this area will offer the greatest potential. With regards to Smart Grid, after North America, the key markets we see are developed nations of Europe, Middle East, China and Japan.

ZP: What can we look for from Alcatel-Lucent in '13 to revolutionize the Smart Grid experience?

JL: Smart Grid is a fast-growing priority market for Alcatel-Lucent and we are investing significantly in this area. We will have new product announcements in 2013 but unfortunately it is too early to talk about them.

Q&A with:

Alstom Grid | www.alstom.com

ZP: How has energy storage for the Smart Grid evolved over the past year, where does the industry stand today?

AG: Last year has seen a lot of activity in E-Storage:

- Regulation: We saw a clarification of EU and US position on the topic, which however see E-Storage as a good solution to solve some grid issues will not update the regulation in the short term. However government has launched tenders for large demonstrations involving E-Storage.
- Commercial: A higher level of tender and request has been seen on the market and customers have been requesting more detailed technical information.
- Technical: Technical: high level of activity there with a many technical solution being presented and demonstrated.

ZP: How can Alstom Grid's Smart Grid solutions help utilities integrate energy storage into their respective electric systems?

AG: First, Alstom Grid's business is to provide solution to solve electrical grid problems and to improve grid performance. E Storage fits in that picture, it will be in the year to come a tool for Electric utility to run their Grid as SVC or FSC are today. From this standpoint Alstom positions itself as a turnkey supplier of electricity storage solutions for utilities. It will be of course based on its in-house developed DC technology, taking advantage of its wide experience in power electronics.

ZP: Which geographic markets offer the greatest potential for energy storage integration over the next five years?

AG: Europe, USA and China

ZP: What can we look for from Alstom Grid in '13 to revolutionize the energy storage experience for the Smart Grid?

AG: Alstom has heavily invested to develop the technology to support its positioning. In 2012 Alstom launched a common laboratory with CEA-INES for the development of advanced storage solutions; taking advantage of the most adequate storage technologies (chemistries, ultracap or else) and optimizing the electrical solution to supply the most competitive solutions to electrical utilities.

Q&A with:

GE | www.ge.com

ZP: What current stake does GE have in energy storage as it relates to renewables and power conversion technologies?

GE: GE recently signed a business cooperation agreement with Arista Power, Inc., a manufacturer, designer, and integrator of renewable generation, management and distribution systems, to jointly market Arista's new Power on Demand System that will incorporate GE's Durathon batteries. GE has also agreed to acquire Converteam, a world leader in power conversion technologies, which is collaborating with Prudent Energy to design and install Vanadium Flow Batteries for power grids in the US and China.

ZP: What are recent investments by GE in energy storage?

GE: With a product strategy of producing longer-term batteries, GE invested $100 million to produce the next-generation industrial battery technology. The result is the Durathon Battery which is a sodium-nickel battery that is thermally sealed in ceramic enabling operation in extreme temperatures and without air conditioning. They are 50% smaller and 25% lighter than traditional batteries enabling more energy to be stored in a smaller space. They can me modularly configured and since the cells are recyclable, the batteries represent a sustainable technology.

ZP: Can you tell expand on GE's Durathon battery?

GE: GE's Durathon battery, backed by Durathon Battery Energy Storage Systems, is marketed for stationary and motive applications in telecommunications, power generation, grid operation, energy management and UPS systems. Batteries are excellent for ambient conditions and ideally suited for hot climates and off-grid locations, particularly in telecom applications with poor and unreliable grids such as portions of Southeast Asia and remote China (with transportation concentration for mining equipment, locomotives, and heavy construction). The technology also blends well as a hybrid with diesel. As a compliment to energy storage, GE has different control systems in the works around all areas, especially solar, DMS and EMS systems, Dynamic Response and Peak Load applications.

ZP: What can we look for from GE in '13 to revolutionize the energy storage experience for the Smart Grid?

GE: GE's near-term focus is to take the technology into mass production. In July, GE opened a manufacturing facility in Schenectady, New York which will eventually be served by 450 employees. GE's first customer is a South African Company,

Megatron Federal. The company will pair GE's batteries with diesel generators in an effort to save 53% on fuel, 45% on maintenance, and 60% on generator replacements.

Q&A with:

IEEE | www.ieee.com

Representing IEEE: S. Massoud Amin, D.Sc. (Director, Technological Leadership Institute (TLI); Honeywell/H.W. Sweatt Chair in Technological Leadership; Professor, Electrical & Computer Engineering, University Distinguished Teaching Professor)

ZP: What are some companies and/or Smart Grid pilots that are managing energy storage systems effectively?

IEEE: Under the Federal Recovery Act Funding for Major Smart Grid Program Activities, a portion which is for the "Smart Grid Regional and Energy Storage Demonstration Projects" amount to about $685 million total. An example is the City of Glendale, California, under the Advanced Metering Infrastructure (AMI) Smart Grid Initiative. The State of California total project cost is $51,302,105 and the Federal funding is $20,000,000.

The City of Glendale's AMI Smart Grid Initiative involves system-wide deployment of advanced meters, use of customer systems and in-home displays, installation of distribution automation equipment systems, and management of distributed energy storage. There are several more that amount to the total of $685 million, including:

Utility	Location	Rating	Technology
Battery Storage For Utility Load Shifting Or For Wind Farm Diurnal Operations And Ramping Control			
Duke Energy	Goldsmith, TX	24 MW	Proprietary
Modesto Irr. District	Modesto, CA	25MW / 75MWh	Zn-Cl Flow
SoCal Edison	Tehachapi, CA	8MW / 32MWh	Lithium Ion
Frequency Regulation Ancillary Services			
PPL Corp/Midwest Energy	Tyngsboro, MA; Hazle Township, PA	20MW / 5MWh	Flywheel
Distributed Energy Storage For Grid Support			
Painesville Municipal	5 locations in OH, PA, VA, IN, MA	1MW / 6-8MWh	Vanadium Redox
Detroit Edison	Hanover, MA; West	25kW / 50kWh (20	Lithium Ion

In a related note, also please see an article, "Storage: An Indispensable Ingredient in Future Energy", which we just published in July at: http://smartgrid.ieee.org/july-2012/619-storage-an-indispensable-ingredient-in-future-energy

ZP: How can energy storage transform the global market for microgrids?

IEEE: Energy storage systems present an opportunity to transcend the power balance paradigm by allowing energy to be stored and released at different times. The potential applications of grid-integrated energy storage systems cover the entire electric power delivery supply chain, from generation to end-use, and potential benefits range from improved frequency regulation and dynamic stability to superior utilization of renewable and distributed energy resources.

Having had experiences with microgrids, such projects that focus on university campuses, communities, and cities may offer the right scale and very practical environments for testing Smart Grid systems. The projects are generally

intermediate-scale deployments that investigate the entire range of issues that arise with Smart Grid and they can be used to create a diversity of goods and services that provide value to consumers. The research experiences and findings that result from these projects can have very meaningful implications for other organizations that are deploying large or small systems.

We have investigated the optimal planning and operation of energy storage systems in the power distribution system from the consumer's perspective. Two specific applications are chosen to illustrate the benefits of improved energy management and service reliability provided by energy storage systems: customer premise energy storage and distributed energy storage systems (DESS). Optimization models and solution methodologies are developed for both applications, and simulations are performed to compare and contrast various storage technologies, operational settings and solution algorithms.

For example, we are building a microgrid at the Morris campus of the University of Minnesota. The project essentially serves as a living laboratory of our efforts to make the university a "net zero" Smart Grid, one that produces as much energy as it consumes.

We have employed a holistic systems approach for all of our work on this project. It engages faculty, postdocs, researchers, undergraduates, consumers from across the local community, as well as utilities from the wider Smart Grid Coalition in Minnesota to build consensus on issues such as microgrid configuration, cost-effectiveness, and security. This community involvement is very characteristic of campus-based projects and it can play a vital role in the advancement of Smart Grid generally because, in this era of policy gridlock, it's hard to build consensus to accomplish meaningful things at the national level.

From an overall North American power system perspective, microgrids are closer to consumers who are the innermost part of the multi-layered, end-to-end system. Like Russian nested dolls, smaller units such as microgrids can be encompassed or integrated within larger systems. Considering the whole system, our first strategy should be to expand and strengthen the transmission backbone (by adding about 42,000 miles of high-voltage transmission lines to the existing 450,000 miles of 100KV and higher, at a total cost of about $82 billion), augmented with highly efficient local microgrids that combine heat, power, and storage systems, as a Smart Grid with self-healing capabilities (total cost, $17-24 billion annually for 20 years). The costs cover a wide variety of enhancements to bring the power delivery system to the performance levels required for Smart Grid. They include the infrastructure to integrate distributed energy resources and achieve full customer connectivity but exclude the cost of generation, the cost of transmission expansion to add renewables and to meet load growth and a

category of customer costs for Smart-Grid-ready appliances and devices.

Until recently, the costs associated with implementing energy conversion and storage systems have outweighed their benefits and the investment in storage technology research and development was limited. The only storage technology that has been widely implemented is pumped hydro, which involves pumping water from a low elevation to a high elevation reservoir where it is stored and later released to turn hydro-turbines and generate electricity.

Despite technological and economic challenges, a recent confluence of industry drivers has spurred utilities, regulators, researchers and private companies to rethink electric energy storage. These economic, regulatory and technological trends have begun to make storage solutions economically feasible. The following trends and policies are a few of the many important industry drivers:

- Economic: Higher price differences between on-peak and off-peak power

- Technological: Technological maturation of advanced battery technologies due to investments in R&D for consumer and transportation applications

- Regulatory: A 2011 Federal Regulatory Energy Commission (FERC) mandate that supports fast-ramping short term regulation resources, such as energy storage technologies.

- Regulatory-Economic: State-mandated renewable portfolio standards (RPS) have increased the penetration of renewable resources on the grid.

- Military: Critical military installations are increasingly vulnerable to commercial electric grid outages, creating a need for long-duration emergency backup solutions.

In summary, grid energy storage systems present an opportunity to transcend the power balance paradigm by allowing energy to be stored and released at different times. The ability to move energy in time opens up a plethora of potential applications that cover the entire electric power value chain, from generation to end-use. Energy storage can be used to balance the variability of renewable generation and, properly deployed and integrated, can increase grid reliability and asset utilization. As we have shown, energy storage systems can also provide direct benefits to end users through reduced rates, decreased outage costs and improved power quality.

About Zpryme Smart Grid Insights:

Zpryme-powered Smart Grid Insights Publication, Practice and Advisory Board help organizations understand their business environment, engage consumers, inspire innovation, and take action. Zpryme Smart Grid Insights represents an evolution beyond traditional market research and consulting: combining sound fundamentals, innovative tools and methodologies, industry experience, and creative marketing savvy to supercharge clients' success. At Zpryme, we don't produce tables and charts; we deliver opportunity-focused, actionable insight that is both engaging and easy-to-digest. For more information regarding our custom research, visit: www.zpryme.com.

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**Jon Arnold is also a member of Zpryme's Smart Grid Advisory Board.*

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