Global Energy Storage Market Overview & Regional Summary Report

2015

Ecoult Energy Storage Project at Hampton Wind Farm

Editor: Steve Blume, President Energy Storage Council

Contributors:

ESC Energy Storage Council

CESA California Energy Storage Alliance

CNESA China Energy Storage Alliance

DNV·GL

IESA India Energy Storage Alliance

neca national electrical and communications association

EcoSmartElectricians™

Sumitomo Electric, Yokohama Works, 1MW-5MWh, this application provides for demand side management, renewable Integration and renewable firming.

ENERGY STORAGE COUNCIL

www.energystorage.org.au
ABN 32 006 824 148

PRESIDENT: Steve Blume
CHIEF EXECUTIVE: John Grimes

PO Box 231, Mawson ACT 2607
info@energystorage.org.au
Phone: 1300 768 204

Global Energy Storage Market Overview & Regional Summary Report 2015

Published by the Energy Storage Council

Edited by Steve Blume

ISBN: 978-0-646-94626-9

Please note that all historical figures in this report are valid at the time of publication and will be revised when new and proven figures are available. All forecast figures are based on our knowledge at the time of publication.

Contents

Executive Summary

This report is designed to introduce the field of energy storage, and identify the major trends in this sector globally.

This report identifies the applications, geographies and technologies that will experience the greatest growth in the short term.

It looks at the economics of key applications and timeframes for their adoption.

By capacity more than 99% of global energy storage is today made up of large scale pumped hydro projects.

These large infrastructure projects have been developed at low cost where the geography and water storage infrastructure have been suitable. The vast size of these projects has dwarfed all other forms of energy storage.

However, there is a significant shift underway, as other forms of storage, battery storage in particular, are increasingly economic in a wide range of applications.

Battery manufacturing costs are falling, (as battery factories scale up for the production of electric vehicles), and have the potential to be a major disruption to the electricity and transportation sectors.

For the first time industry analysts, researchers, government and the media are paying attention to a market they have not covered before.

This report is intended to be an introductory report. For more detailed reports and market intelligence, see the bibliography at the end of this document, or make contact with your nearest Energy Storage Association (listed as a collaborating organisation at the end of the Report).

Collectively we have a global network of suppliers, customers and consultants that can help you go to the next level and learn more about this fascinating and exciting sector.

An Industry Poised for Rapid Growth

These are some of the big trends pushing growth of the energy storage market globally:

Electric Vehicles (EVs) Time has Come – subsidies for EV's in China, and a rapidly growing global market is fueling a massive scaling up of battery technology.

Cheaper Storage – these economies of scale are leading to rapid decreases in the cost of battery technology in particular, with spin off benefits for other applications.

Micro-Grids Becoming Economic – as grid infrastructure costs climb, and areas that do not have grid access are electrified, micro grids supported by distributed energy generation and energy storage are becoming the rational economic choice.

Changed Pricing Regimes – an additional major driver is increasing fixed and demand charges in some areas driving behind-the-meter installations. The impact of renewables and storage on long term business models, and the narrowing number of customers from which to get a return on an existing asset and investment base has seen a reaction of increased fixed charges and introduction of demand charges. Charges and financing structures will remain volatile for some years as new models evolve to deal with distributed energy networks – with storage as a core part.

At the same time we are seeing a global trend towards greater energy independence, as consumers seek to have active control when it comes to their energy needs. This is driven by a wish for empowerment over rising costs and the certainty that renewables with storage offers, 'cost of living insurance', but also by resiliancy and reliability – individuals taking out 'energy insurance' so they have at least some power during grid outages. These 'prosumers' have the potential to quickly change how grids are managed and priced.

The contributing associations look in detail at the key energy storage regions of the world in 2015.

The International Renewable Energy Agency (IRENA) has estimated the world would need 150 GW of battery storage by 2030 if it is to meet the desired target of 45 per cent of power generated from renewable sources.

Japanese giants Toshiba and Panasonic are vying with South Korean conglomerates Samsung and LG for leadership in the fast-growing battery energy storage market for power generated from renewable sources such as solar and wind.

Other contenders in energy storage such as Nissan's AESC, Mitsubishi's joint venture partner GS Yuasa and Chinese maker BYD, (which has Warren Buffett's Berkshire Hathaway group as a key shareholder), are concentrating on the market for battery-powered electric vehicles.

No matter how you look at it, technology, economics and government policy are coming together to unleash a new force in global electricity in the form of the global energy storage market.

Technology Overview

Energy storage is literally all around us in our modern lives. This includes a wide range of technology and techniques for storing energy for use at a later time, from the electric hot water tank at your home of business, to the batteries that start your car, and power your laptop and smartphone.

Energy storage technologies are classified as follows:

- Mechanical Energy Storage – such as pumped hydro
- Electrochemical Energy Storage – such as batteries of various types
- Thermal Energy Storage – such as molten salt
- Chemical Energy Storage – such as energy converted and stored as hydrogen

The leading technologies are briefly introduced below.

Mechanical Energy Storage

Mechanical energy storage has been by far the largest form of energy storage around the world so far. The technology categories are briefly introduced below.

Pumped Hydro Storage (PHS)

Far and away the most widely used form of bulk-energy storage is currently pumped hydropower storage (PHS). By using a simple combination of water and gravity, excess energy is used to pump water uphill to be stored in a reservoir. When energy is scarce, water is released to flow downhill, drive a turbine and create electricity.

PHS accounts for more than 99% of bulk storage capacity worldwide: around 127,000 MW across 200 large sites globally.

Key advantages include low cost, reliability, and the ability to provide power at high levels for many hours.

However, traditional PHS incorporated with large scale hydro dams has limited capacity for expansion due to geographic constraints, although there is some room to retrofit pumped hydro to a few existing sites. Expansion of traditional large scale PHS is limited by the scope and duration of permitting and construction which can result in many years between the decision to build a PHS plant and the date of grid connection.

This is leading to innovation as non-traditional approaches are developed.

In Denmark one approach is to build artificial islands with wind turbines and a deep central reservoir. When the wind blows, the energy is used to pump water out of the reservoir into the sea. When power is needed, seawater is allowed to flow back into the reservoir, driving turbines to produce electricity[1].

In other examples steep topography with a fall of 800-1000m are being exploited. This approach includes pumping seawater up to coastal cliff tops, as has been done in a pilot facility in Japan[2] and in a number of sites in the Middle East – UAE[3] and Saudi Arabia.

PHS can be used to stabilise and reduce wholesale electricity prices at peak demand times, balance network loads, and increasing the spread of renewable energy.

Four types are already commercially deployed: Pumped Hydroelectric Storage, Sub-surface Pumped Hydroelectric Storage, Surface reservoir Pumped Hydroelectric Storage, and Variable Speed Pumped Hydroelectric Storage.

Compressed Air Energy Storage (CAES)

Compressed air energy storage (CAES) involves compressing air and storing it in large repositories, such as underground salt caverns, and releasing it to drive a turbine during periods of demand.

CAES works best at the utility scale of 10MW to 100MW, and is used as a source of flexible supply to provide continuous load response and peak-generation.

Two commercial CAES plants are in operation in Germany and Alabama in the US.

One supplier SustainX, uses standard steel pipes to store the compressed air, allowing its systems to be installed wherever they are needed.

Another company General Compression (GC)[4] is working cost effective CAES solutions that could deliver between 200-400MW hours of storage in conjunction with wind farms. CAES would be able to deliver this output at a quarter of the price of battery technologies. GC has received funding from sources like oil giant ConocoPhillips and the largest utility in the US, Duke Energy.

Flywheels

A flywheel energy storage system is a mechanical battery storing kinetic energy in the form of rotating mass[5].

The system has a flywheel or rotor usually of composite materials[6], mounted in an evacuated cylinder using high precision bearings and other components, and is accelerated to high speed using off-peak and/or renewable electricity with the energy being stored as rotational energy.

The speed of the flywheel energy storage system is reduced when energy is extracted from the system – with near immediate response and high reliability. Traditionally fly wheels have been designed with high power to energy ratios, with typically short discharge durations and this remains the case.

1 http://www.greenpowerisland.dk

2 http://www.jpower.co.jp/yambaru/ (Japanese) & https://en.wikipedia.org/wiki/Pumped-storage_hydroelectricity

3 http://www.irena.org/remap/IRENA_REmap_UAE_report_2015.pdf

4 http://www.generalcompression.com

5 http://energystorage.org/energy-storage/technologies/flywheels

6 http://www.compositesworld.com/blog/post/composite-flywheels-finally-picking-up-speed

Flywheel energy storage systems have a long life, great reliability, require little maintenance and high rates of efficiency.

Flywheel systems are scalable; smaller sizes have been in use since the 1940s in trucks and buses[7], were advanced in the 1980's with Volvo taking a lead[8]; and larger stationary energy solutions are in use with 5MW to 50MW units in development.

Liquid Air Energy Storage (LAES)[9]

Liquid Air Energy Storage (LAES) is a large scale, long duration energy storage solution, with sizes ranging from 5MW to over 100MW.

In a LAES system electricity is used to cool air until it liquefies, and stores the liquid air in a tank.

When power is needed, liquid air is brought back to a gaseous state, (by exposure to ambient air of via waste heat from industrial processes) and used to turn a turbine to generate electricity.

The technique uses well-established components with long life times (30 years +), resulting in low technology risk.

LAES can be retrofitted onto industrial waste heat/cold applications such as thermal power stations, steel mills and LNG terminals to improve system efficiency.

Hot Water Systems

Storing excess energy as hot water is already widely used in managing grid loads in current fossil fuel and nuclear generation networks across the world. In most countries around 30% of all stationary energy use is to heat water.

Applications are emerging to harness this energy source in insulated tanks, including:

- Low temperature systems (under 120°C) for domestic and commercial use including for space heating in homes, residential buildings, offices, local distribution of district heating systems;
- Medium temperature systems (under 175°C, but over 120°C in normal operation) in larger scale hot-water distribution systems like district heating, and in process application systems requiring those higher temperatures; and
- High temperature systems (over 175°C in normal operation) very large distribution and process application systems requiring even higher temperatures.

Solutions are emerging that harness the excess energy from solar photovoltaics at a domestic or commercial application, and instead of exporting that excess energy to the grid, it is harnessed to drive an electric resistance heater in an insulated tank.

These hot water storage units can be used to offset periods of high demand for water heating on the grid.

Electrochemical Energy Storage

Electrochemical batteries are a rapidly growing segment of the energy storage market. Batteries are all around us in portable electronic equipment, uninterruptable power supplies (UPS) and beyond.

Batteries come in a flexible array of sizes, and are optimised for numerous applications. With costs falling as scale ramps up, these batteries are experiencing rapid growth.

The major electrochemical battery fields are introduced below.

Batteries - Advanced Lead Acid Battery

Until now lead-acid technology has been ubiquitous, and has been the basis of car batteries for nearly a century. However, there are limitations[10] of this technology. There are two broad advanced lead acid battery technologies:

Nickel–Cadmium battery (Ni-Cd) has been in production since 1910, and while not leading on measures of energy density or first cost Ni-Cd do not need complex management systems and have a long life with reliable service.

Nickel–Metal hydride battery (Ni-Mh) which were used in the initial Toyota Prius and other hybrids, but the characteristics have been surpassed by lithium technologies which have also come down the price curve while increasing the performance curve.

Lithium-Ion (LI-ION) Battery

The first lithium ion battery was released in 1991 and their high energy density and efficiencies of more than 90% made them suitable for consumer electronics.

The term 'Lithium-Ion' refers to a range of different electrochemical chemistries, where lithium-ions transfer between electrodes during the charge and discharge reactions.

Li-ion cells can be built in plastic or metal cylinders and rectangles, or in pouches. These cells can then be arranged in series or parallel arrays, each controlled by an energy management system, and scaled up to any size needed.

The system design of Li-ion batteries, including control and mechanical housing are all important to safe operation of these batteries.

Increasingly companies are developing larger format cells for use in energy storage applications, and it has become the technology of choice for the electric vehicle industry.

In turn the economies of scale from mass production are bringing down the costs for other applications as well[11],

---

7 https://en.wikipedia.org/wiki/Gyrobus

8 http://trid.trb.org/view.aspx?id=167026

9 http://energystorage.org/energy-storage/technologies/liquid-air-energy-storage-laes

10 http://www.nature.com/news/2010/100106/full/463018a.html

11 https://gigaom.com/2015/01/11/is-the-solar-panelbattery-combo-ready-to-change-energy-markets/

including domestic solar PV coupled applications to micro grids and large on grid storage.

Electric car company Tesla and Panasonic have been working closely on lowering costs of their lithium-ion batteries significantly and with Tesla's "gigafactory". Tesla's PR is hard to beat, but many other Li-Ion manufacturers in China and elsewhere are also well underway with construction of 'giga-facilities' – including BYD, Lishen and Samsung.

Several years ago lithium-ion batteries cost around $1,000 per kWh. Navigant Research reports that Tesla pays about $200 per kWh for its Panasonic battery cells today, and that price could drop as low as $130 per kWh by 2020.

Other startups have also emerged in this sector for large on grid use such as Quion Energy and Ambri[12]. There are also a number of grid storage system integrators such as STEM, Green Charge Networks, and Green Smith, which claim to be storage "technology agnostic," but nevertheless are currently designing systems exclusively with Lithium-Ion batteries.

Sodium Sulfur (NaS) Battery

Originally developed by the Ford Motor Company in the 1960's and sold to Japanese company NGK, sodium sulfur batteries store energy by chemically dissociating sodium polysulphide into sodium and sulphur.

Operating at between 300 to 350 degrees C, over 270MW of NAS batteries have been deployed over 190 sites in Japan, in stationary on grid peak shaving applications.

The largest NAS installation is a 34MW (245MWh) unit for stabilizing wind energy in Northern Japan.

Flow Systems

The primary difference between conventional batteries and flow batteries is that in a conventional battery energy is stored in an electrode material, but as an electrolyte fluid in a flow cell.

This allows for almost instantaneous recharging by replacing the electrolyte fluid, and recovering the spent material to be re-energized.

Different classes of flow batteries have been developed including redox, hybrid and membraneless.

An excellent exposition of flow batteries can be found at the site of our US partners the Energy Storage Association (ESA).[13]

Thermal Energy Storage

In these applications thermal heat is stored via some medium. By extracting that heat energy can be produced. In turn the system can be 'recharged' by introducing heat again at a later date.

These are typically large scale solutions.

Pumped Heat Electrical Storage (PHES)

PHES may be suitable in the 2MW-5MW scale when short response times for stored energy are not required.

By using argon gas under pressure to heat crushed rock, the PHES system stores energy in the form of heat. It uses a heat pump to transfer heat from the 'hot store' (around 500 degrees C) and the 'cold store' (around -160 degrees C).

Incoming energy drives a heat pump, compressing and heating the argon and creating a temp differential between the two tanks. During high demand, the heat pump runs in reverse as a heat engine, expanding and cooling the argon and generating electricity with efficiency of around 72-80%.

Concentrated Solar Power (CSP)

Concentrating Solar Power uses the heat from the sun, by concentrating it via an array of mirrors onto a specific focal point.

Operating at extremely high temperatures, this heat can be used to heat super critical steam to drive an electricity turbine.

In one application the CSP is used to heat molten salt, with the 'hot salt' stored in insulated containers. When energy is needed (typically at night) the energy can be extracted as the molten salt is transferred to a 'cold salt' tank.

To be recharged the 'cold salt' (typically 350 degrees C) is reheated by the sun and the process repeats.

Whilst thermal energy storage is expensive, a CSP plant with energy storage can decrease the cost per kWh produced and

Redflow's large scale battery, up to 660kWh of energy storage in a standard 20ft shipping container.

12 https://gigaom.com/2015/01/11/is-the-solar-panelbattery-combo-ready-to-change-energy-markets

13 http://energystorage.org/energy-storage/storage-technology-comparisons/flow-batteries

can dispatch electricity during periods of peak demand.[14] It has also been used in Spain and the US to provide additional capacity when daytime demand is high.

Chemical Energy Storage

By creating a chemical reaction, we can create a new substance that holds potential energy to be used at a later date.

While there are several elements the most advanced at this stage are introduced below.

Hydrogen Storage[15] and Solar Power to Gas (P2G)

Hydrogen is used in stationary, portable and transportation applications. By volume hydrogen is not very energy dense, however when stored as a liquid, or cold compressed it has potential for use in light vehicles.

A number of hydrogen storage solutions are already in the market, including in Australasia[16], with Japan a long-term leader in automotive solutions and residential storage[17]. For the transport sector the hydrogen solutions face stiff competition from EVs and there are hundreds of competing technologies for residential storage.

A solar to gas plant in Stuttgart uses electricity from solar PV to produce hydrogen from water. To make methane, the hydrogen is reacted with CO_2 from decomposing sewage and agricultural waste as at nearby biogas plant.

While this has potential to scrub CO_2 from the air, this is still an immature technology, with high upfront costs.

Technology Deployment

Pumped hydro accounts for over 99% of installed capacity globally. The remaining 1% is deployed as follows:

- Compressed Air – 44.8%
- Sodium Sulphur – 31%
- Lithium-ion – 11%
- Lead Acid – 7%
- Nickel-cadmium – 2.7%
- Flywheel – 2.5%
- Redox-flow – 1%

Capital Costs

Referenced sources have widely varying technology costs by type.

The range of costs in USD per watt is as follows:

- Lead Acid – $1.50 - $2.00
- Flow Batteries – $3.00 - $4.00
- Lithium Ion Batteries – $1.00 - $1.80
- Sodium Sulphur Battery – $2.50 - $3.00
- Pumped Hydro Storage – $1.05 - $4.00
- Compressed Air Storage – $0.80 - $9.00
- Molten Salt Storage – $2.50 - $5.20

AECOM lists the assumptions underpinning these price estimates.[18]

This puts the Levelised Cost of Electricity for the above technologies per kWh as:

- Lead Acid – $0.25 - $0.35
- Flow Batteries – $0.25 - $0.30
- Lithium Ion Batteries – $0.25 - $0.50
- Sodium Sulphur Battery – $0.40 - $0.60
- Pumped Hydro Storage – $0.05 - $0.15
- Compressed Air Storage – $0.10 - $0.30
- Molten Salt Storage – $0.15 - $0.35

14 http://arena.gov.au/files/2014/12/ARENA_RAR-report-20141201.pdf
15 http://www.energy.gov/eere/fuelcells/increase-your-h2iq
16 http://www.sefca.com.au
17 http://reneweconomy.com.au/2015/japan-makes-big-bet-hydrogen-economy-22639
18 http://arena.gov.au/files/2015/07/AECOM-Energy-Storage-Study.pdf

Applications

The market applications for energy storage solutions are broad.

Choosing the right technology for the right application, at the right scale, is vital to get the best outcome for customers.

As the costs of energy storage fall, new applications become economic. Further, the flexibility of energy storage allows for multiple applications to be bundled together to provide value to both the system and a customer.

Some of the leading existing applications are outlined below:

Fuel Saving – avoiding costly fuels (transportation and off grid applications)

Arbitrage – collecting energy when it is cheap/abundant, and selling it when it is expensive/scarce

Network Management – managing load balance and power quality on networks, mitigating intermittency of renewable generation resources

Upgrade Deferral – delaying or eliminating the need for expensive electricity infrastructure upgrades

Customer Bill Management – combined with solar PV or standalone, shaving peak demand or overall capacity to reduce energy costs for customers operating under high tariffs

Time Shifting – avoiding high electricity tariffs by using stored energy during expensive time of day pricing

Back Up Supply – providing back up power as a UPS for specific equipment or loads

Hot Segments of the market include:

- Electric Vehicles
- Micro grids
- Edge of grid applications
- Consumer storage – in conjunction with solar PV

There is also a range of applications specific to each global region. For example powering telecommunication towers in India, and solar PV domestic storage in Australia. These regional drivers are discussed in more detail following.

Image courtesy of Off-Grid Energy Australia

International Market Review

Contributing Energy Storage Associations have provided an update on their region. These updates provide a concise overview of the energy storage market in that region.

Global Market Overview

The US has the largest market for energy storage both by number of projects and by installed capacity. By year's end 2014, the US had commissioned 95 energy storage projects, with installed capacity exceeding 357 MW. Japan is second in installed capacity with 310 MW, and China second in number of projects with 63. In 2014, the US installed the most new ES, 34.4 MW, with China and Europe following with 31 MW and 27.7 MW respectively.

The following regions are covered in more detail below:

- USA
- China
- Japan
- India
- Germany
- Australia

USA Market Review

At a Glance:

- In 2014 62MW of energy storage was installed
- In 2015 220MW of energy storage is projected to be installed[19]
- Some US States have world leading energy storage incentive programs, (most notably California) which has adopted a 1,325MW target by 2020
- By 2019 the energy storage market is forecast to reach 861MW annually and be valued at $1.5 billion
- In 2014 90% of storage capacity was in front of the meter
- In 2014 the weighted average system prices were $2,064/kW

Active Policy Landscape

Since 2011, at least 10 states have introduced a total of 14 bills related to energy storage. While not all have passed the majority have been related to utility scale storage (including transmission, distribution and utility scale generation), as follows:

- Financial Incentives
- Technical and policy pathways
- Introducing energy storage procurement standards

Existing Energy Storage Market

According to GTM Research and the Energy Storage Association (ESA), there was 62 MW of energy storage deployed in the United States in 2014.

In 2015 it is forecast that this will grow by 250% with 220 MW is projected to be installed in that year alone. Further, it is anticipated that the energy storage market will continue to grow at a rapid rate from that point.

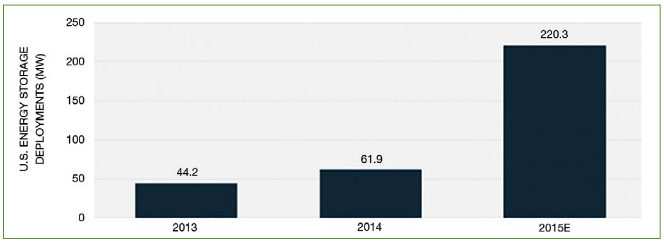


FIGURE: U.S. Energy Storage Deployments 2013-2015E
Source: GTM Research/ESA U.S. Energy Storage Monitor

Front of Meter Focus

Around 90% of the new energy storage was installed in front of the meter, with 10% installed behind the meter at residential and commercial/government sites.

Behind the meter segments however, saw a dramatic increase in the fourth quarter of 2014. GTM Research expect behind the meter storage to account for 45% of the overall market by 2019. Behind-the-meter installations will be led in markets where customers are exposed to high energy and peak demand charge tariff such as California & New York.

Already the economics for energy storage makes sense in a broad array of applications, and system costs are falling rapidly. This is expected to result in significant overall market growth in 2015.

PJM and California Lead the Way

Geographically, PJM[20] and California are taking the early lead in policy and regulation, and wholesale market structure to encourage the uptake of energy storage.

In 2014 two-thirds of all deployed capacity was located in PJM. And within this 70% of all deployments were based on lithium-ion batteries. The bulk of these PJM installations have been deployed to provide grid frequency regulation services, with the lithium-ion systems having discharge duration of 20-30 minutes.

By 2019, GTM Research expects the U.S. energy storage market to reach 861 MW annually and be valued at $1.5 billion, (about 11 times its size in 2014).

California is the largest residential and non-residential market, with a cumulative 1.0 MW residential and 6.9 MW of non-residential energy storage. Hawaii is the second-largest residential market, with 320 kW of cumulative deployments; PJM (excluding New Jersey) comes in second in non-residential deployments with 0.8 MW[21].

---

19 http://www.greentechmedia.com/articles/read/the-us-deployed-40.7-mw-of-storage-in-q2-2015-best-quarter-in-2.5-years

20 PJM Interconnection LLC (PJM) is a Regional Transmission Organization (RTO) in the United States. It is part of the Eastern Interconnection grid operating an electric transmission system serving all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia.

21 U.S. Energy Storage Monitor Q1 2015: Executive Summary

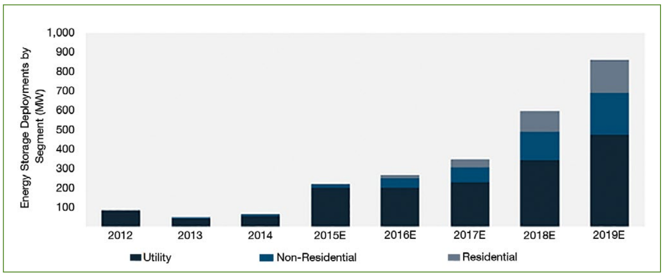


FIGURE: U.S. Energy Storage Deployments by Segment, 2012-2019E. Source: GTM Research/ESA U.S. Energy Storage Monitor

Participating Companies

The following companies are participating in the US market:

Source: GTM Research/ESA U.S.

California

The California Public Utilities Commission (CPUC) adopted a 1,325 MW procurement target for electricity storage by 2020, with target increasing every two years from 2016 to 2020.

The targets are broken into three categories for use:

- Transmission connected
- Distribution connected
- Behind the meter

Already 378 MW of new storage capacity is underway as a result of the Californian procurement targets. California's new 50% renewables mandate is likely to result in substantial incremental need beyond the 1.325 GW target for storage, at both the bulk system level and distribution level. The CPUC is currently considering whether the target itself needs to be adjusted in light of the increased renewables mandate and other policy and commercial developments.

Southern California Edison Tehachapi Wind Energy Storage Project

California is home to the world's largest lithium ion battery - an 8 MW/32 MWh battery in Tehachapi CA.

In a tender conducted in 2014 Southern California Edison chose to purchase over five times the amount of energy storage it was required to. With an energy storage mandate of 50 MW, it actually procured 261 MW.

Some notable awards were provided to the companies STEM and Advanced Microgrid Systems which will install behind-the-meter storage systems that will also receive system capacity payments.

In addition the target is divided by each of California's three investor owned utilities as shown in the table below.

Use case category, by utility	2014	2016	2018	2020	Total
Southern California Edison					
Transmission	50	65	85	110	310
Distribution	30	40	50	65	185
Customer	10	15	25	35	85
Subtotal SCE	90	120	160	210	580
Pacific Gas & Electric					
Transmission	50	65	85	110	310
Distribution	30	40	50	65	185
Customer	10	15	25	35	85
Subtotal PG&E	90	120	160	210	580
San Diego Gas & Electric					
Transmission	10	15	22	33	80
Distribution	7	10	15	23	55
Customer	3	5	8	14	30
Subtotal SDG&E	20	30	45	70	165
Total – all 3 Utilities	**200**	**270**	**365**	**490**	**1,325**

Source: Californian Energy Storage Alliance

China Market Overview

At a Glance

- In 2014 China installed 31MW of energy storage
- In 2014 China had a cumulative total of 84.4MW of energy storage installed
- Currently in China 74% of the energy storage battery market are lithium-ion, 17% are lead acid, and 9% are flow batteries
- Government policy is creating an environment for significant market growth
- By 2020 China is on track to have over 10 million electric vehicles on its roads

China Market Context

China's electric power network is the largest in the world, both in terms of installed generation capacity and total electricity produced.

Home to some of the world's largest wind and solar farms, China has set aggressive renewable energy targets.

The development of the energy storage industry began relatively late in China; however, the industry has seen rapid developments in the last two years.

Current projects concentrate on:

- Electric vehicle applications
- Renewable energy integration
- Distributed generation
- Micro grid projects

Lux Research forecasts an USD$8.5 billion energy storage market by 2025. Transport applications will dominate with $7.4 billion, or 85% share of the revenues. Stationary applications will earn $1.3 billion. Overall, revenues will grow slower than volumes on account of continually falling battery and systems prices. There are over 100 lithium-ion battery manufacturers in China, many focusing on lithium iron phosphate, (such as BYD, China Aviation Lithium Battery (CALB), Lishen and others).

These firms are principally focused on grid scale energy storage and electric vehicle markets. BYD has installed numerous projects at home and abroad, including a battery project in the PJM frequency regulation market. As production increases amongst manufacturers, price will continue to fall both domestically and internationally.

Advanced Lead Acid Batteries

Lead-acid batteries, and advanced lead-acid batteries in particular, have been a popular choice for solar integration projects on islands and in remote regions that otherwise rely on imported diesel for power generation.

Chinese vendor Narada has supplied lead carbon batteries to solar integration island projects and other micro grid projects. This includes a 1 MWh installation in the western Chinese province Xinjiang and two projects totaling 2.5 MW on Lu Xi island near Wenzhou.

In China lead-acid remains a low-cost, proven technology. By adding carbon battery performance is significantly improved for power intensive applications, as solar PV ramp control.

Rapid Energy Storage Growth

While the global ES market is steadily developing, China's ES industry is growing rapidly. In March 2015, the CCP Central Committee and the State Council issued the "Guiding Opinions on Deepening Electricity System Reforms". This has spurred intense activity in developing and deploying new energy and advanced energy storage technology, and has been a major boost for the industry.

CNESA data shows that by the end of 2014, China had 84.4 MW of ES installed capacity on the grid (not including pumped hydro, CAES and thermal storage), an increase of 31 MW, a growth rate of 58%. This is a great increase compared to the 14% growth in 2013.

Global Storage Installation

Technology	2012		2013		2014	
	Capacity (MW)	Ratio	Capacity (MW)	Ratio	Capacity (MW)	Ratio
Na-S Battery	328.1	50%	334.1	45%	334.1	40%
Li-ion Battery	155.7	27%	212.8	29%	290.0	35%
Lead-acid battery	80.8	12%	89.0	12%	92.0	11%
Flow battery	36.3	6%	40.7	6%	41.3	5%
Flywheel	27.9	4%	31.9	4%	53.9	6%
NiCad battery	27.0	4%	27.0	4$	27.0	3%
Supercapacitor	0.5	<0.1%	0.5	<0.1%	2.0	<0.2%

Chinese Storage Installation

Technology	2012		2013		2014	
	Capacity (MW)	Ratio	Capacity (MW)	Ratio	Capacity (MW)	Ratio
Li-ion battery	32.7	88%	35.6	69%	58.5	72%
Lead acid battery	0.7	2%	3.9	15%	13.6	17%
Flow battery	3.6	10%	8.6	15%	7.7	9%

Source: CNESA

Lithium ion batteries make up 74% of China's installed ES capacity, followed by lead acid batteries and sodium sulfur batteries at 14% and 10%. These three technologies make up about 98% of China's market.

Global Energy Storage Applications

Applications	2012		2013		2014	
	Capacity (MW)	Ratio	Capacity (MW)	Ratio	Capacity (MW)	Ratio
Generator-side (ancillary services)	110.1	17%	122	17%	153	18%
Renewable integration	347.2	54%	374	51%	384.8	46%
Grid-side	127	20%	142	19%	159.7	19%
User-side	43.6	7%	60	8%	102.8	12%
EV solar charging station	12.1	2%	13.2	2%	13.2	2%

China Energy Storage Applications

Applications	2012		2013		2014	
	Capacity (MW)	Ratio	Capacity (MW)	Ratio	Capacity (MW)	Ratio
Generator-side (ancillary services)	-	-	2	4%	2	2%
Renewable integration	17.5	48%	23	44%	23	28%
Grid-side	4	11%	4	8%	4	5%
User-side	2.9	8%	12	23%	41	50%
EV solar charging station	11	30%	11	21%	11	14%

Source: CNESA, 2014

**Note: Renewable integration refers to energy storage installed with solar PV or wind*

User-side applications account for most of China's market, 50%, which includes island, remote area, industrial park, and low-carbon city applications.

Renewable energy grid integration and electric vehicles make up the second and third largest applications, at 27% and 13%, with most of the former being in wind farm energy storage, and most of the latter being in solar + storage EV charging stations, V2G (vehicle to grid) applications, demand response charging, and second-life EV battery usage.

National Policies

While there are no policies that directly address energy storage, a series of reforms have been announced in 2015 that support the growth of this industry. 13 energy policies are to be released in 2015 and 2016, six of which were released as of June 1, 2015. These 13 policies include large capacity storage, high efficiency energy storage, and EV charging infrastructure policies, and a *Renewable Energy Quota Management Approach*, which is similar to renewable portfolios standards. Mid-July 2015 also saw the release of another energy policy that concerns the guidelines and demonstrations of distributed microgrid systems (both on and off-grid). The policy was seen as a main push to promote the wider use of energy storage for grid-applications. The main spotlight will be on the formal introduction of Energy Storage, as a targeted energy sector with specific policy support, in the forth-coming 13th Five-year Plan to be announced after October 2015. Preliminary drafts on policy guidelines and growth plans with active inputs and comments from the industry and research communities were finalized and formally submitted to the National Energy Administration (NEA) towards late July, 2015.

In addition, supply and demand reflective energy pricing is set to be introduced within the next 5 years. This will lead to greater flexibility and market responsiveness. Up until now, non-dynamic electricity prices have been set by policy, not market forces. Off-peak electricity policies will be put into practice in 2015. Preliminary power system reform is also in the works. (Expanded on below – see electricity reforms and Policy No. 9).

More Renewable Energy

The most ambitious renewable energy program in the world is underway in China. By the end of 2015 there will be 100 GW of installed **wind capacity**, and 200 GW by 2020.

By the end of 2015 there will be 35 GW of installed **solar capacity** and China is on track to deliver 50 GW by 2020. Driven by a 0.42 CNY/kWh national feed-in tariff, provinces and local governments often apply their own supplemental FITs on top of the national one, leading to final FITs up to 0.70 CNY/kWh. While the deployment of solar PV has been mainly centralized to date, new policies are increasingly favoring distributed installation.

The Rise of Electric Vehicles

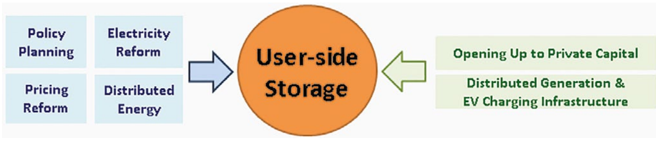
In 2015 100,000 EVs are to be deployed in China, with a target of 10 million EVs by 2020. This will require the installation of significant energy related infrastructure before then.

Grid Storage Policy

Increasingly grid regulations are being implemented that support the installation of grid scale energy storage in China. Guidelines have also been issued for grid development, new urban construction, coordination of disturbed power supply and EV deployment guidelines.

In China Southern Power Grid's 13th Five-year Plan, the development of micro grids is being encouraged.

Private capital investment is now permitted in grid-connected distributed energy, EV charging infrastructure, pumped hydro, and peak shifting and frequency regulation resources.



These New Electricity Reforms, outlined in Policy No. 9 and "Guiding opinions on deepening electricity system reforms", represent the biggest reforms in China's energy sector in 10 years.

They will open the market to competition and new capital, and promote independent trading structures.

CNESA can provide addition information on the significant reforms in the Chinese electricity sector that will address almost all existing barriers.

These include:

- Ancillary service compensation to increase
- Peak shifting compensation to increase
- Compensation for pairing of wind farms with coal fired generation to increase
- Demand-side management (DSM) compensation to increase and is being encouraged
- Distributed generation is being encouraged
- Internet of Energy (Internet+) has become a very hot topic in policy making circles

Leading Projects

Selected leading projects include:

- Turpan: 1MWh lead carbon battery; micro grid energy storage (Narada)
- Woniushi: 5MW/10MWh vanadium redox flow battery; wind farm energy storage (Rongke Power)
- Zhangbei: 14MW/63MWh lithium-ion battery, 2MW/8MWh vanadium redox flow battery, renewable energy integration (multiple vendors)
- Beijing: 2MW lithium-ion battery; generation-sited frequency regulation
- Yushu: 3MW/12MWh lead acid battery; remote area energy storage

- Luxi Island: 2MW/4MWh lead carbon battery, 500kW ultracapacitor; island energy storage (Narada, SPS)
- Shenzhen: 20MW/40MWh lithium-ion battery; end-user energy storage (BYD)

Source: CNESA 2014

Japan Market Overview

At a Glance

- Japan has ambitious targets to produce half of the world's batteries by 2020
- Japan has a subsidy program for 66% of the cost for homes and business that install lithium-ion batteries
- Japan has been a world leader in sodium-sulfur batteries with around 300MW installed to date
- Japan has the world's only sea-water pumped hydro installation
- Japan has a target of 30% renewables by 2030

Japan's Energy Needs

Against the backdrop of the Fukushima earthquake in 2011, Japan has shut down over 60GW of nuclear capacity, and significantly increased deployment of renewable energy, adopting a target of 30 percent renewable energy by 2030.

Solar comprises the majority of Japan's clean-energy. Some utilities began announcing last year that their grid capacity is nearing its maximum to absorb intermittent solar power.

Against this backdrop energy storage has become a higher priority for Japanese energy planners.

Japan Targets Battery Market

In 2011 Japan produced around 18% of the batteries used in the global market. Now the Japanese government is aiming for Japanese companies to produce around half of the world's battery storage market share by 2020.

Japan has an active policy approach to energy storage, and develops storage battery industry policies, create future markets and targets global blocks to the adoption of storage technology.

Lithium-Ion Subsidy Program

Japan has a new subsidy program to support the installation of stationary Li-ion batteries by individuals and businesses. The subsidy is set to cover up to two thirds of the cost of the storage system, paid by Ministry of Economy, Trade and Industry (METI) with a budget of $US98.3 million. Payments are capped at US$9,846 for individuals and US$982,000 for businesses installing battery systems with a capacity of 1kWh or more[22].

Other subsidies are available for 50% of stand-alone renewable energy generation with batteries, with separate schemes for community renewables and Earthquake affected areas.

In addition Japan's Ministry of Economy, Trade and Industry has allocated US$779 million to help factories and small businesses improve energy efficiency. It also wants to encourage energy storage systems at solar power stations or substations.

The ministry outlined the reasons for the subsidy scheme, reiterating Japan's acute energy problems since the 2011 Fukushima nuclear accident. One reason is that Japan is interested to assess how the integration of renewable energy sources could be aided by using storage that manages peak supply and demand as well as stabilising power supply. Another reason is that Japan is keen to measure the effect of battery mass production on battery prices and the extent that battery storage could aid energy self-sufficiency.

Sodium Sulphur Batteries

NaS batteries have been developed commercially by NGK Insulators in Nagoya, Japan. Japan now has an installed capacity able to supple its grid with about 300 MW when extra power is needed. By contracts the US has 10 MW of NaS capacity installed.

In addition Japan has the only operating sea-water pumped hydro storage facility in the world.

Leading Manufacturers

Leading Japanese battery manufacturers include:

- Li-ion - GS Yuasa, Hitachi, Hitachi, Maxell, Mitsubishi Heavy Industry, NEC, Panasonic (Sanyo), Toshiba
- Lead Acid - GS Yuasa, Shin-Kobe Electric Machinery
- Sodium-Sulfur - NGK Insulators
- Redox Flow - Sumitomo Electric

Larger Projects

Some recent large-scale energy storage projects include:

- Wakkanai Solar Project– Solar PV - 5MW, NAS battery 1.5MW
- Miyakojima Microgrid – Solar PV 4MW, Wind 4.2MW, NAS battery 4MW, Lithium-ion 0.2MWh
- Tohoku Electric On Grid – Lithium-ion 20MWh
- Hokkaido Electric Power Co On Grid – Redox Flow Battery 60MWh

22 AECOM Energy Storage Study 2015

India Market Overview

At a Glance

- Many parts of India have no or poor quality electricity supply
- Lead Acid technology is widespread for domestic, commercial and industrial use
- Diesel replacement offers a significant commercial opportunity for energy storage in India
- Approximately 70% of 400,000 telecommunications towers loose power each day – another key market
- India has a target of 40GW of renewable energy capacity by 2030
- $3.5bn allocated to support EV's in India to 2022
- Potential ESS market estimated at 16.4GW by 2020

India is one of the fastest growing economies in the world, with current electricity generation capacity of 250 GW to meet the needs of over 1.2 billion people. India's per capita annual consumption of energy at ~900 kWh is one of the lowest in the world, even when compared to developing countries like Brazil and China.

Despite considerable growth in the power sector, many parts of the country continue to face severe power shortage as consumption has been increasing at much a faster rate than electricity supply. Those who have access to power suffer from shortages and also poor quality of power supply. Industries maintain diesel powered generators and households have inverters with batteries as backup for unscheduled power cuts as a result of voltage and frequency fluctuations.

Energy Storage Systems (ESS) market in India is in its infancy with significant upside market potential. India has pumped hydro storage facilities with a total of just 7,000 MW of installed capacity. Apart from these facilities there are few other utility scale storage projects currently operating in India, though in recent times there are encouraging developments for distributed ESS in India.

Recent Activities

Some notable activities in ESS market and landscape in India in recent times are as follows:

- PGCIL (Power Grid Corporation of India) invited bids for ESS demonstration projects for 500 KW / 250 kWh capacity under three categories, namely, Lithium Ion Battery, Advanced Lead Acid Battery and Sodium Nickel Chloride/ Alkaline/ Flow Battery.
- MNRE proposes to support demonstration projects for ESS to assess feasibility of ESS technologies for small scale and grid connected MW scale renewable energy applications. The demonstration projects are expected to help in acquiring the desired technical knowledge, economic & market assessment and insights on the approaches for shaping up a focused program in this key area.
- Auto-components manufacturer Minda Industries, will partner with the Japanese multi-national Panasonic for manufacturing of automotive batteries in India and is planning to invest Rs 700-800 crore (~ USD 120-130 Million) in three years towards capacity expansion and acquisitions.
- Indian government plans to build 100 smart cities with a budget of Rs 7,000 crore (~ USD 1.2 billion). Over 130 million smart meters are likely to be installed under this scheme and smart net metering might discourage storage at customer end. However, there is a possibility of application of ESS for improvement of power quality, which will be one of the key agenda of this program.

Key Opportunities

The majority of energy storage employed in India includes lead-acid batteries which are used by residential, commercial as well as industrial customers. Lead Acid batteries will remain the back bone of UPS and backup power for most of the customers in years to come, but there is a huge potential for replacing these traditional lead acid batteries for applications, where the limitations on duty cycle, cycle life and operating temperature can prompt existing customer for adoption of advanced solutions with lower cost of ownership.

- Renewable integration: To ensure smooth evacuation and distribution of the green energy across the country, PGCIL has decided to set up an exclusive cross country green corridor for renewable energy involving an investment of Rs 42,000 core (US $ ~7 billion) over a period of five years. The investment has been aimed to transmit 40 GW of renewable energy capacity by 2030. This would also include other work such as ESS, real time monitoring system and setting up of renewable energy management center.
- Diesel replacement: Most parts of India suffer from significant power shortages. To ensure uninterrupted power supply almost all industries, commercial complexes deploy diesel generator (DG) as back-up and emergency supply. The estimate varies between 25,000 to 35,000 MW for installed capacity of DGs in India. During 2008-2012, around 7% of total diesel consumption in India was used for power generation. Per unit DG costs are around **Rs**

Microgrid in India. Image courtesy of India Energy Storage Alliance.

15-50 per kWh (~15-83 US cents / kWh) whereas utility tariffs are around **Rs** 4 to 5/kWh for most customers. This provides lucrative opportunity for ESS application.

- Introduction of ancillary service markets: CERC is currently working on policy framework to introduce ancillary markets in India with initial focus on frequency regulation. Based on the supply – demand mismatch and the anticipated share of variable renewable resources in the supply mix, various experts at the Regional Load Dispatch Centers (system operators) anticipate that India needs to allocate 2-3% of the generation as frequency regulation resource to improve the grid frequency. Based on the current installed capacity of 250 GW, this could result in a frequency regulation market size of 4-5 GW to open up once CERC finalizes the regulations.
- Rural Electrification: Despite massive rural electrification plans, India has over 24,000 un-electrified villages with 300 million people no access to electricity. Even for the electrified villages, only a small fraction of the households are connected and have power available for less than 8 hours per day. Off-grid power generation augmented by local renewable energy (wind, solar, bio, hydro) in micro-grid mode is therefore an attractive option to energize nearly 125,000 villages. Under the Deen Dayal Upadhayaya Gram Jyoti Yojna (DDUGJY), the central government will fund over USD$830 million for microgrid development in all the villages of India. So battery based ESS in such microgrids can help in maintaining intermittency of renewable energy generation and increasing the efficiency of diesel generators.
- Telecom Sector: India has one of the largest telecom markets in the world with over 400,000 telecom towers. On an average, 70 percent of the approximately 400,000 mobile towers in India face power outages in excess of 8 hours a day. Due to unreliable power supply the huge number of telecom towers use diesel generators and many of these tower has hybrid renewable power supply. In both the cases, battery based ESS can help in saving large diesel cost and can firm the renewable energy supply.
- Electrifying the transportation sector: Indian government has allocated Rs ~20,000 crore (US$ ~3.5 billion) over the next eight years to promote hybrid and pure electric vehicles, through research and development, infrastructure and subsidies under National Electric Mobility Mission Pla 2020 with a goal of adoption of 6 million Hybrid (HEVs)and Electric Vehicles (EVs) across various customer segments. The Indian government has passed ordinance to legalize e-rickshaws and e-carts in the country after they were banned in July 2014 after the Delhi High Court Order. There is a huge market potential for e-rickshaws in India in states like Delhi, Uttar Pradesh, Punjab, West Bengal, Maharashtra and Bihar where these rickshaws can replace the manually pulled rickshaws. Number of e-rickshaws in Delhi had crossed 200,000. The lead acid batteries worth of over US$ 100 million have been installed in e-rickshaws in India. As mentioned in India Energy Storage Market Overview Report, the total potential for ESS in India in period of 2015 to 2020 is estimated worth 16445 MW.

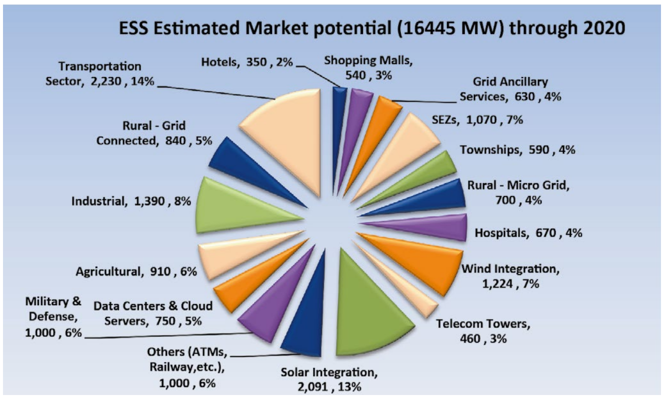


Figure 1: ESS estimated market potential (MW) through 2020
Source: India Energy Storage Overview Report by India Energy Storage Alliance

Opportunities and Challenges

Although India presents a huge market for emerging ESS, there are also significant challenges. There is no existing legal framework or regulation currently in place that specifically identifies ESS as an asset to interact with the electric grid. Since ESS devices both consume and supply power to the grid, their participation in the system need to be carefully designed.

Some of the existing barriers in India that have prevented wide scale adoption of ESS technologies include poor financial conditions of various state owned distribution companies, electricity markets are new and currently limited to day ahead and short term energy trading, power quality (such as stable grid frequency) is viewed as a luxury by some of the regulators and lack of awareness about successful implementation of state of the art technology options.

Despite all the above challenges ESS is gaining importance in India as it is starting to get attention amongst the policy makers for role in enabling integration of higher levels of renewables while maintaining grid reliability and power quality.

Regulators in progressive states as well as CERC and forum of regulators have started to evaluate options for ESS integration. In 2014, Ministry of New and Renewable Energy (MNRE) invited Dr Rahul Walawalkar to join the National Standing Committee on Energy Storage and Hybrid Solutions to guide and advise the MNRE in defining need based priorities, research and development needs, thrust areas, field applications, policy initiatives in area of energy storage technologies and also renewable energy based hybrid systems.

This shows the interest amongst the policy makers to understand the advances in technology. With an ever increasing demand backed by the government policy initiatives, ESS is set to become a key aspect towards the overall goal of India's progressive energy initiatives.

German Market Overview

At a Glance

- *Energiewende*[23] policy will reduce greenhouse gas emissions 80% on 1990 levels and increase energy efficiency
- High renewables penetration will drive adoption of energy storage with a target of 27% by 2020 and 50% of electricity generation from renewables by 2030[24]
- Germany has great experience with high penetration of RE into its grids creating business opportunities for grid management software and control systems.

Germany's Energy Needs

Germany has committed to close its nuclear power plants following the Japanese Fukushima earthquake in 2011 and has established policies to significantly increase deployment of renewable energy beyond its original, and current EU, target of 40% renewables by 2030 (see above). All nuclear plants will be closed by 2022[25].

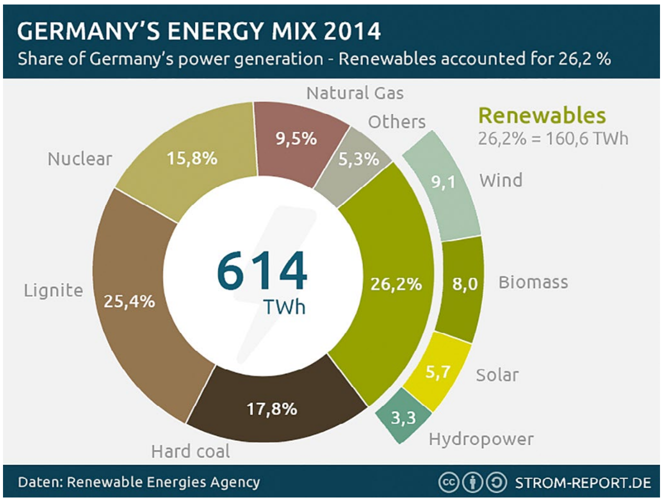
Germany has significant hydro generation, but these have been exploited with few opportunities existing to expand them. There has been rapid deployment of rooftop and solar and some large PV arrays, but land is expensive and there is resistance to transfers from existing agricultural uses. Wind generation continues to be expanded and transmission links to other EU and Scandinavian countries are being augmented.

Large parts of Germany's electricity infrastructure have very high variable output distributed renewable energy generators – the surprise has been that the impacts on grid stability and reliability has been able to be managed. The close down of large capacity plants has become the driver for massive energy storage deployment at utility scale.

A paper prepared for the IEA in 2014 suggests that at a 50% RE level in 2030 there would be an 'excess' of renewable power up to 27 G – about ~ 2 Tw of renewable production, around 1% of the electricity produced by wind and photovoltaics equating to the need for a storage capacity requirement of ~250 GW by 2030[26]. Most will come from pumped hydro, but a significant amount from other storage.

Storage Policy Settings

The German energy storage market has experienced a massive boost in recent years. This is due in large part to Germany's ambitious energy transition *(Energiewende)* project. The reduction of CO_2 emissions and the expansion of renewable energies as an alternative to fossil power plants are the central premises behind this concept. Greenhouse gas emissions are to be reduced by at least 80 percent (compared to 1990 levels) up until 2050 and Germany will gradually phase out all of its nuclear power plants by 2023 – and in doing so will revolutionize its energy infrastructure.



Source: http://strom-report.de/strom-vergleich/#energy-mix-germany

Germany is already a front-runner in renewable energy development. Renewable energy sources currently produce around 30 percent of all electricity consumed in Germany. In line with the goals of the German government, this share is to be increased to at least 80 percent of electricity consumption by 2050. Solar power, onshore and offshore wind power will be the main pillars of renewable energy production.

Germany's *Energiewende* brings with it huge challenges. The integration of fluctuating renewable energies into the electricity grid demands innovative storage solutions and major investment in the transmission grid. Substantial and fast reacting storage capacities are needed to balance out short-term fluctuations.

Long-term storage solutions are also needed to shift loads through the seasons. Germany's geographical makeup places significant restrictions on the possibility of developing new pumped storage capacity. This makes the use of new storage technologies and smart grids an imperative.

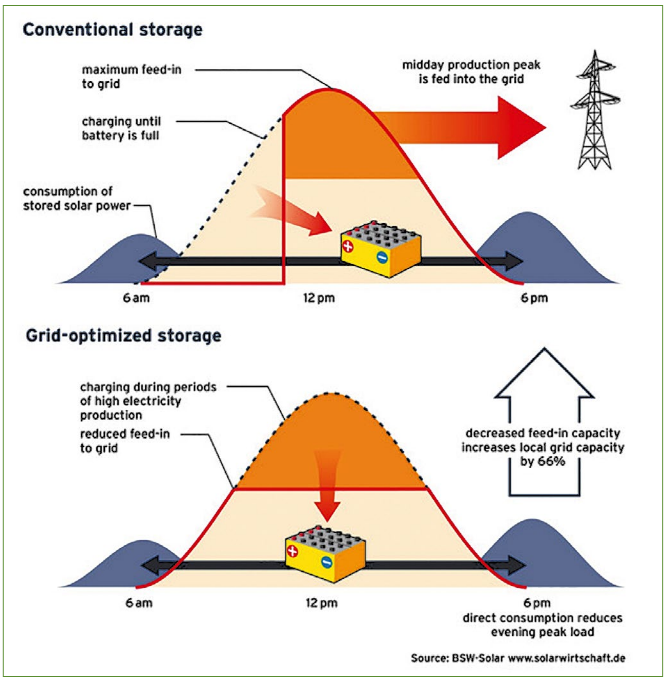
To this end, energy storage systems – from small and large-scale batteries to power-to-gas technologies – will play a fundamental role in integrating renewable energy into the energy infrastructure to help maintain grid security. The German Federal Ministry for Economic Affairs and Energy and the German Federal Ministry of Education and Research are funding 186 projects on energy storage with a total of 202 million euros.

23 http://www.gtai.de/GTAI/Content/EN/Invest/_SharedDocs/Downloads/GTAI/Fact-sheets/Energy-environmental/fact-sheet-energy-storage-market-germany-en.pdf

24 http://www.bmub.bund.de/en/

25 http://www.bmub.bund.de/en/press/press-releases/detailansicht-en/artikel/minister-hendricks-nuclear-phase-out-progressing-1/?tx_ttnews%5BbackPid%5D=1

26 https://www.iea.org/media/workshops/2014/egrdenergystorage/Hufendiek.pdf



German Storage Market

Changes to the Fit rates for residential and small commercial rooftop PV in Germany and retail rates above €0.30 kWh are factors forcing greater self consumption with around 20% of new PV installations now including battery packs. This is tough market though with rooftop PV near saturation with multiple players and fewer customers. Battery storage is being offered as a retrofit with a large number of brands in the marketplace. Germany has had a low-interest loan program since 2013 to support PV owners wishing to add storage of under 30kW to their new system[27].

As well as a range of trials there is already operational deployment at grid scale underway by German utilities. According to Deutsche Bank, the German market for electrical storage devices is expected to at least double between 2012 and 2025. An associated investment of roughly 30 billion euros will be required in Germany alone over the next 20 years. By 2040 at the latest, some 40 terawatt-hours (TWh) of electricity will have to be stored on a regular basis, in some cases over a period of several months.

Leading Manufacturers

German companies and institutes have been at the leading edge of energy management systems combining ITC for grid management and storage technologies[28]. The following are just a few examples.

Siemens began developing energy storage devices several years ago. Siemens Energy Storage (Siestorage) is a modular system that links high-performance lithium-ion batteries with power electronics for connection to the electricity grid. Their system offers grid stabilisation for low-voltage grids of ~400 volts and distribution grids with 10 to 30 kilovolts slide-in units housed integrated into climate-controlled containers. This system also offers black start capabilities.

Siemens has many other technologies in its arsenal including flywheel storage[29], an instant load shedding solution with software and control systems to detect and manage large load sites to take them down and bring them back online[30].

Belectric has installed an energy storage system at a large-scale solar power plant in Germany at Alt Daber solar farm. Belectric's Energy Buffer Unit at Alt Daber is the first such installation in Europe to operate on the primary operating reserve market[31]. The Alt Daber solar power plant. With a capacity of 2 MWh (megawatt hours), the unit provides the power flexibly and regardless of the time of day to actively stabilize the power grid.

In July, Bosch installed what is believed to be one of Europe's biggest grid-scale lithium-ion (Li-ion) and vanadium redox flow battery systems to store excess wind energy in the small community of Braderup-Tinningstedt[32] near Stuttgart. This system will deliver one megawatt of power for four hours. In other words, it has a capacity of four megawatt hours, enough to power around 400 single-family detached homes for one whole day.

Younicos[33] has built Germany's largest on-grid battery system for the German Green utility WEMAG AG[34]. With a rated-power of 5 Megawatts and a capacity of 5 megawatt-hours, the battery helps to stabilize the grid frequency in wind-swept West-Mecklenburg[35].

Innovative storage company Sonnenbatterie[36] has had success with its software platform which integrates solar

27 http://www.solarwirtschaft.de/fileadmin/media/pdf/infopaper_energy_storage.pdf

28 http://forschung-energiespeicher.info/en/

29 http://www.siemens.com/innovation/en/home/pictures-of-the-future/energy-and-efficiency/smart-grids-and-energy-storage-flywheel-energy-storage.html

30 http://www.siemens.com/innovation/en/home/pictures-of-the-future/energy-and-efficiency/smart-grids-and-energy-storage-dossier.html

31 http://www.belectric.com/en/energy-storage/

32 http://www.bosch-presse.de/presseforum/details.htm?txtID=6100

33 http://www.younicos.com/en/home/

34 http://www.wemag.com/

35 http://www.younicos.com/en/projects/07_Schwerin/

panels, lithium-ion batteries and home energy management systems into an “intelligent” system. These systems range from 4.5-kilowatt-hour to 10-kilowatt-hour systems with modular systems sized up to 60 kilowatt-hours. They have partnered with clean energy retailer LichtBlick to offer a ‘cluster’ model that again is software integrated services to give owners and grid shared benefits through optimisation of local generating and storage facilities[37].

Australia Market Overview

At a Glance

- Australia’s off-grid energy storage is estimated to be 1 GW in the long term
- Domestic grid connected energy storage is leading market demand
- The first subsidy program for energy storage has begun in Adelaide
- Standards are required to support industry growth

City of Adelaide

In the first example of storage specific subsidies in Australia, the City of Adelaide is offering businesses, residents, schools and community organizations in the city of Adelaide an incentive of up to $5,000 for installing energy storage, as part of an expanded Sustainable City Incentives Scheme.

The incentive is aimed at driving community investment in solar + storage, as well as in energy efficiency and electric vehicles as part of the state government’s plans for a carbon neutral Adelaide.

Off Grid Energy Storage

To date most battery storage systems have been installed off-grid, in combination with PV and/or wind supported by diesel fuel generators.

A large geography, with a small population, and the expansion of mining in remote Australia are all driving off grid energy storage take up. AECOM has forecast that the renewable off-grid market potential could grow to over 200 MW in the short to medium term and over 1 GW in the longer term.

Some examples of off grid energy storage projects include:

- King Island - 3 MW / 1.6 MWh Ultrabattery (advanced lead acid technology) provided by Ecoult to reduce diesel consumption, help maintain stability of the grid and increase the time that the network can operate on 100% renewable energy.
- Lord Howe Island - 400 kW /400 kWh of battery storage, along with stabilisation and demand response technology, which is expected to reduce diesel consumption by up to 70% and completely offset diesel when renewable generation is high.

Renewable Energy Driver

Australia has the largest penetration of grid connected domestic scale solar PV in the world, with 22% of all free standing homes having solar PV and or solar hot water on their roofs. Over 4GW of solar PV capacity has been installed to date across over 1.5 million homes.

Federal government policy will underpin around 20% of Australia’s energy from renewable energy (mainly wind and solar PV) by 2020. In South Australia, wind for the first time on 28 June 2014 between 4:10 am and 4:35am delivered 100% of that states energy.

Solar PV Driving Energy Storage

There are a range of factors driving energy storage take up in Australia, however significant market demand is coming from customers who have installed solar PV. In order to maximize the return on investment, and responding to very low feed in tariffs, customers want to capture excess solar energy they produce during the day to use in the evening.

This is leading to significant interest in behind the meter, grid connected energy storage solutions. There are now a several companies offering small-scale energy storage (mainly lithium-ion) in the range of 2kWh to 21kWh.

This is considered the most mature market segment in Australia, and has the potential for significant growth in the short term.

Energy Storage Standards

Grid connected energy storage systems are covered by Australian Standards (AS4777), and there are a number of other applicable standards, including AS3011, AS4086, AS2676, AS4509 and others, but they are currently well out of date and do not provide adequate guidelines for modern batteries, including design, installation, testing, maintenance or safe housing of battery systems. These require urgent updating. The Australian Energy Storage Council is taking the lead on an urgently industry created voluntary standards regime for safety and quality to meet the expected rapid deployment and the absence of current standards.

---

36 http://www.sonnenbattery.com/en/home/?zabbix-web-check=&cHash=a797794ec6e7d643fcd728ca46ab59e1

37 http://www.lichtblick.de/en/lichtblick/schwarmenergi

On-Grid Applications

Regulatory changes mean that increasingly electricity suppliers need to adopt the lowest cost options to deliver reliable power. Increasingly energy storage is becoming a competitive option against other infrastructure upgrade choices.

Battery storage systems are being seriously considered traditional network augmentation. A number of trials for this purpose are currently underway:

- Demand Management – AusNet Services – 1MW/1MWh lithium-ion battery
- Demand Management – Ausgrid – 5kWh and 10kWh zinc bromide flow batteries across 5 homes
- Fringe of Grid – Ergon – Lithium-ion batteries being installed in key areas
- Smoothing supply - Hampton Wind Park - 1 MW/1.8 MWh Ultra battery provided by Ecoult to reduce mismatch between wind availability and demand

Manufacturers in this market segment include:

- Bosch
- RedFlow
- Magellan Power

With a number of others having announced their intention to enter this market including:

- Tesla
- AGL
- Origin

Some companies are focusing on managing domestic energy storage such as Reposit Power.

Zinc bromide flow batteries ready for shipping, at Redflow's gigawatt factory within Flextronics North America.

Energy Storage and Grid Integration in Australia - July 2015

Review of Current Market Conditions by National Electrical Communications Association (NECA) and EcoSmart Electricians

neca | national electrical and communications association

EcoSmartElectricians™ Connecting you to a more sustainable future

Overview

Driven primarily by regulatory mandates in the United States, Europe and parts of the Asia Pacific region the energy storage industry as a whole took some substantial steps forward, in 2014 some of the largest single contracts in history were awarded to leading storage companies.

However the Australian energy storage and renewable energy market throughout 2014 and 2015 has been hampered and plagued by uncertainty due to ongoing political review of the country's renewable energy target and more recently the review of the operating and investment objectives of the Clean Energy Finance Corporation.

The commercial sector of the energy storage and renewable energy market has seen battery and other system component costs falling rapidly, allowing energy storage to become an economical alternative to the traditional power generation methods for certain applications. Driven by the provision of innovative financing models there has been consistent growth and substantial interest from the main stream community in the adoption and uptake of technology options. However uncertainty of future policy and direction has had a negative effect on uptake and market activity.

Lithium Ion (Li-ion) based energy storage systems continue to gain popularity with consumers as increasing capacity of large scale manufacturing facilities and improving competitive market forces are driving down the cost for stationary Li-ion staring applications.

As energy efficiency continues to become the highest priority in construction and building operation more complex equipment and solutions are emerging and demand from consumers is increasing. Awareness is growing through the community of the benefits of improved product technology, energy efficiency and beneficial aspects of electric vehicles.

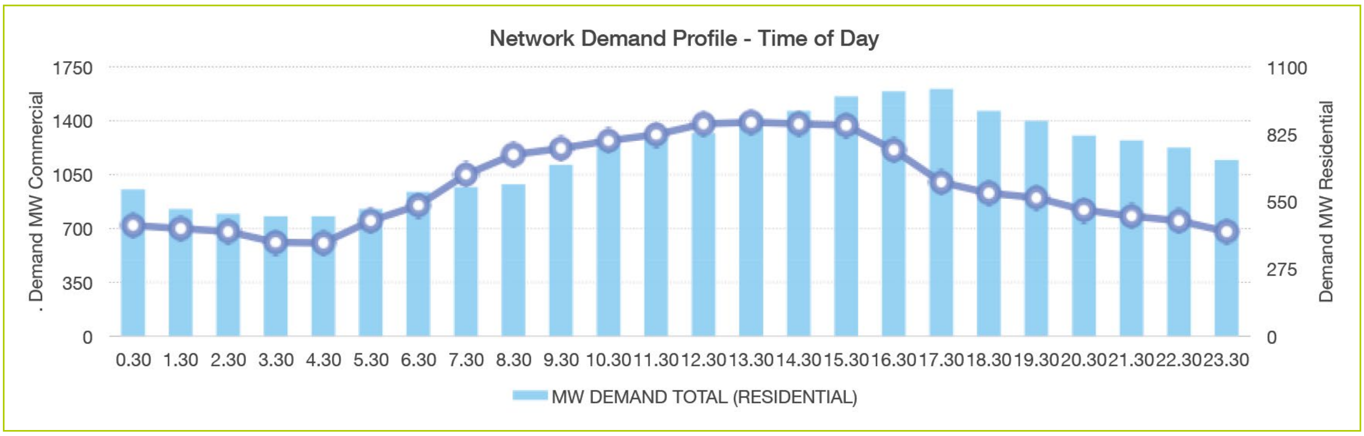
The growing number of plug in electric vehicles (PEVs) on roads will most likely have profound impacts on the grid if the adoption of PEVs is not aligned with associated vehicle-grid integration technologies. The adoption and integration of these technologies presents significant opportunity for the electrical industry, grid operators and the automotive industry who traditionally have been quite disparate. Smooth and seamless transition to future technology uptake will be contingent on co-operation between multiple industry sectors and government legislation and regulation.

The impact on the grid of PEVs in Australia is negligible at this period of time but as more PEVs populate the roads, utilities are likely to become increasingly concerned with

Network Demand MW (Hot Summer Day Profile)

TIME	MW DEMAND TOTAL (COMMERCIAL)	MW DEMAND TOTAL (RESIDENTIAL)
0.30	720	600
1.30	700	520
2.30	680	500
3.30	610	490
4.30	605	490
5.30	750	520
6.30	850	590
7.30	1050	610
8.30	1180	620
9.30	1220	700
10.30	1270	785
11.30	1310	815
12.30	1380	830
13.30	1390	900
14.30	1380	920
15.30	1370	980
16.30	1210	1000
17.30	1000	1010
18.30	930	920
19.30	900	880
20.30	820	820
21.30	780	800
22.30	750	770
23.30	680	720

This chart demonstrates the shift in network demand throughout the day by use sector (Commercial vs Residential) for a hot summer day.
Commercial network demand corresponds to business hours of operation between 0600 to 1700.
Residential network peak demand is driven by activity later in the day from 1500 to 1700.
Commercial network peak demand could be reduced by use of Solar PV operation during daylight hours to reduce the 0600 to 1700 peak load.
Residential network peak demand could be reduced by use of battery storage to reduce peak demand after sunset.



managing the demand created through vehicle recharging and the drastic increases in demand during peak times when PEV owners return from work and plug in their vehicles.

Analysis of grid network load profiles throughout the year indicate that maximum peak demand occurs during hot summer days. Load profiles for grid networks providing energy to commercial customers record a reasonably wide time gap during commercial operating hours of 9am - 5pm due to stable and consistent HVAC load. Grids servicing residential customers' record hot summer day peaks from 4pm - 8pm has households return at the end of the day and demand for small scale HVAC and cooking / entertainment systems proliferate. Increased demand for PEV charging during the times will only exacerbate the network demand problems.

Substantial opportunity exists for the integration of battery storage systems in conjunction with solar photo voltaic (solar PV) to minimise and enhance the existing grid infrastructure.

Uptake and adoption of these technologies will gradually eventuate driven by economic market forces. However the uptake and benefit to community will be accelerated through proactive positive legislation drive by government policy in Australia.

Image courtesy of Energy Safe Victoria.

Further Reading

European Energy Storage needs 2020-2030 - EASE submission of 2013[38]

International Energy Agency (IEA)[39] and especially its roadmaps program[40] which includes the 2015 Energy Storage Road Map[41].

The US Department of Energy (DoE) is a significant resource with its Global Energy Storage Database[42] to which the ESC is a contributor.

The report by Scandia Labs for the DoE from December 2013 is a valuable overview[43].

The German Energy Transition (Energiewende) program[44] includes storage as part of this massive move to renewables and publishes regularly with updates and other information[45] with their Program G being grid and power storage[46].

There are a number of other groups in the EU aiming at getting increased use of energy storage including the stoRE Project[47].

Japan too is a leader in storage with the Government Ministry of Economy, Trade and Industry (METI) establishing a special group in 2012 called the Storage Battery Strategy Project Team to oversee developments[48].

Japan has plans to spending about JPY 310 billion (about USD 3 billion) over the next 10 years to redevelop its power networks. Much R&D is also occurring in Japan under the Japan Science & Technology Agency (JSTA) especially its Advanced Low Carbon Technology R&D Program[49].

A useful overview of the Japanese plans on energy storage came out of an ARENA workshop in 2014[50].

Japanese companies are moving rapidly into this market for example Hitachi[51], Mitsubishi[52] and of course Panasonic[53].

As this report was being finalised ARENA released a report from AECOM on Energy Storage which is a valuable contribution[54].

The ARENA/CEC Roadmap published earlier this year is also an excellent resource[55].

38 http://www.ease-storage.eu/tl_files/ease-documents/Stakeholders/ES%20Roadmap%202030/EASE-EERA%20ES%20Tech%20Dev%20Roadmap%20 2030%20Final%202013.03.11.pdf

39 http://www.iea.org and http://www.iea.org/topics/cleanenergytechnologies/

40 http://www.iea.org/publications/freepublications/publication/technologyroadmapenergystorage.pdf

41 http://www.iea.org/publications/freepublications/publication/technology-roadmap-energy-storage-.html

42 http://www.energystorageexchange.org

43 http://www.sandia.gov/ess/docs/other/Grid_Energy_Storage_Dec_2013.pdf

44 http://energytransition.de

45 http://www.gtai.de/GTAI/Content/EN/Invest/_SharedDocs/Downloads/GTAI/Fact-sheets/Energy-environmental/fact-sheet-energy-storage-market-germany-en.pdf

46 http://energytransition.de/2012/10/the-grid-and-power-storage/

47 http://www.store-project.eu

48 http://www.meti.go.jp/english/press/2012/0106_02.html

49 http://www.jst.go.jp/alca/en/index.html

50 http://www.irena.org/DocumentDownloads/events/2014/March/6_Tomita.pdf

51 http://www.hitachi.com/rev/pdf/2015/r2015_technology_visionaries02.pdf

52 http://www.mitsubishicorp.com/jp/en/pr/archive/2015/html/0000028099.html

53 http://au.panasonic.com.au/News+and+views/News/2015/May/Panasonic+announces+partnership+to+install+battery+storage+technology+in+2015

54 http://arena.gov.au/files/2015/07/AECOM-Energy-Storage-Study.pdf

55 http://www.cleanenergycouncil.org.au/media-centre/media-releases/april-2015/energy-storage-roadmap.html

Contributing Associations

Australian Energy Storage Council (ESC)

http://www.energystorage.org.au/

Founded in 2014, but active since 2011, the Energy Storage Council is the peak industry body for the energy storage industry in Australia.

As the primary author of this report, the ESC seeks to work cooperatively with other organisations to build the global market for energy storage applications.

We hold regular member events, publish a quarterly magazine Storage Progress, and hold the major energy storage conference and exhibition in May each year.

Contact us at ceo@energystorage.org.au

California Energy Storage Alliance (CESA)

http://www.storagealliance.org

- Founded in 2009 – Janice Lin, Managing Partner of Stratagem Consulting & Don Liddell, Principal of Douglass & Liddell
- Membership includes technology manufacturers, project developers, systems integrators, consulting firms & other clean industry leaders.
- Focus efforts through involvement in the following forums:
    - California Energy Commission (CEC)
    - California Independent System Operator (CAISO)
    - California Public Utilities Commission (CPUC)
    - Federal Energy Regulatory Commission (FERC)

China Energy Storage Alliance (CNESA)

http://en.cnesa.org/

- First and only energy storage industry association in China
- Founded in 2010 as a subcommittee under the China New Energy Chamber of Commerce (CNECC)
- Mission: influence government policy in order to encourage healthy growth of renewable energy through the use of competitive and reliable energy systems

DNV GL

http://www.dnvgl.com/energy

In DNV GL we unite the strengths of DNV, KEMA, Garrad Hassan, and GL Renewables Certification. DNV GL's 2,500 energy experts support customers around the globe in delivering a safe, reliable, efficient, and sustainable energy supply. We deliver world-renowned testing, certification and advisory services to the energy value chain including renewables and energy efficiency. Our expertise spans onshore and offshore wind power, solar, conventional generation, transmission and distribution, smart grids, and sustainable energy use, as well as energy markets and regulations. Our testing, certification and advisory services are delivered independent from each other. Learn more at www.dnvgl.com/energy.

India Energy Storage Alliance (IESA)

http://www.indiaesa.info

- IESA is a service provided by Customized Energy Solutions to promote Electric Energy Storage (EES) technologies and applications in India.
- Founded in 2012
- Mission: To promote Electric Energy Storage (EES) technologies and applications in India by creating awareness among various stakeholders to make the India industry and power sector more competitive and efficient.
- Over 18 energy storage projects are under construction or operational.
- Based on IESA analysis for the potential market for EES in India: based on our analysis we estimate a market potential of over 15 GW for all types of ESS technologies.
- IESA: India Energy Storage Market Assessment for 2013-2020 at the Clean Energy Ministerial New Delhi.

National Electrical and Communications Association (NECA)

http://www.neca.asn.au/

NECA is the peak industry body for Australia's electrical and communications contracting industry that employs more than 145,000 workers and delivers an annual turnover in excess of $23 Billion.

We represent approximately 4,000 electrical contracting businesses throughout Australia.

Additionally, NECA maintains responsibility for the employment, training and skilling of more than 4,000 current and future electricians and contractors through our Group Training and Registered Training Organisations.

NECA represents the electrical and communications contracting industry across all states and territories. We aim to assist our members and the wider industry to operate and manage their business more effectively and efficiently whilst representing their interests to Federal and State Governments, regulators and principle industry bodies.

Please note that all historical figures in this report are valid at the time of publication and will be revised when new and proven figures are available. All forecast figures are based on our knowledge at the time of publication.

ESC ENERGY STORAGE COUNCIL

Magellan Power Energy Storage Battery Management

Australian Energy Storage Council

PO Box 231, Mawson ACT 2607

Telephone: +61 411 407 514

EMAIL: **info@energystorage.org.au**

WEBSITE: **www.energystorage.org.au**

TWITTER: **@energystoragecl**