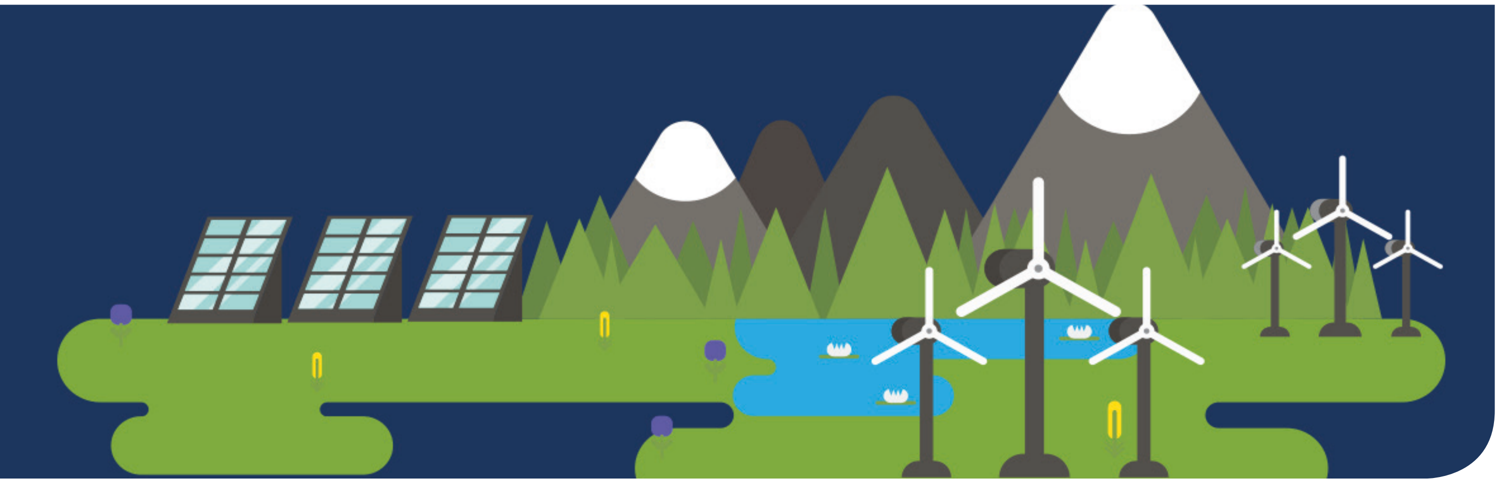


Renewable Energy Storage and Distribution

Fact File

- An IMS Research report expects the market for storing power from solar panels – which was less than $200 million in 2012 – will catapult to $19 billion by 2017 (energystorage.org)

240GW

By 2030

Worldwide, the total amount of energy storage - discounting the electric car market - could reach 240 gigawatts (GW) by 2030 , with batteries as the dominant technology

90GW

EES

Globally electric energy storage (EES) is 90 gigawatts (GW), **which is only 3% of electric power production capacity**

- According to IHS, the global pipeline of planned battery and flywheel projects had reached 1.6 GW by the end of Q4 2015, though suppliers and developers around the world are preparing for a record year in 2016 (renewableenergyworld.com)

Introduction

Electrical grid energy storage is used to manage the flow of electricity within a power grid. For large-scale load levelling on an interconnected electrical system, electric energy producers send low value off-peak excess electricity over the electricity transmission grid to temporary energy storage sites that become energy producers when electricity demand is greater. This reduces the cost of peak demand electricity by making off-peak energy available for use during peak demand without having to provide excess generation capacity that would not be used most of the day.

Why is energy storage so important?

Energy storage fundamentally improves the way we generate, deliver, and consume electricity. Energy storage helps during emergencies like power outages from storms, equipment failures, accidents or even terrorist attacks. But the game-changing nature of energy storage is its ability to balance power supply and demand instantaneously - within miliseconds - which makes power networks more resilient, efficient and cleaner than ever before.

Continued...

Emerging energy storage technologies

Solid state batteries

On its most basic level, a battery is a device consisting of one or more electrochemical cells that convert stored chemical energy into electrical energy. Advances in technology and materials have greatly increased the reliability and output of modern battery systems, and economies of scale have dramatically reduced the associated cost. Continued innovation has created new technologies like electrochemical capacitors that can be charged and discharged simultaneously and instantly, and provide an almost unlimited operational lifespan.

Flow batteries

A flow battery is a type of rechargeable battery where rechargeability is provided by two chemical components dissolved in liquids contained within the system and most commonly separated by a membrane. This technology is akin to both a fuel cell and a battery - where liquid energy sources are tapped to create electricity and are able to be recharged within the same system. One of the biggest advantages of flow batteries is that they can be almost instantly recharged by replacing the electrolyte liquid, while simultaneously recovering the spent material for re-energisation. The fundamental difference between conventional batteries and flow cells is that energy is stored as the electrode material in conventional batteries but as the electrolyte in flow cells.

Flywheels

A flywheel is a rotating mechanical device that is used to store rotational energy that can be called up instantaneously. At the most basic level, a flywheel contains a spinning mass in its centre that is driven by a motor. When energy is needed, the spinning force drives a device similar to a turbine to produce electricity, slowing the rate of rotation. A flywheel is recharged by using the motor to increase its rotational speed once again. Flywheel technology has many beneficial properties that enable us to improve our current electric grid. A flywheel is able to capture energy from intermittent energy sources over time and deliver a continuous supply of uninterrupted power to the grid. Flywheels also are able to respond to grid signals instantly, delivering frequency regulation and electricity quality improvements.

Compressed air energy storage

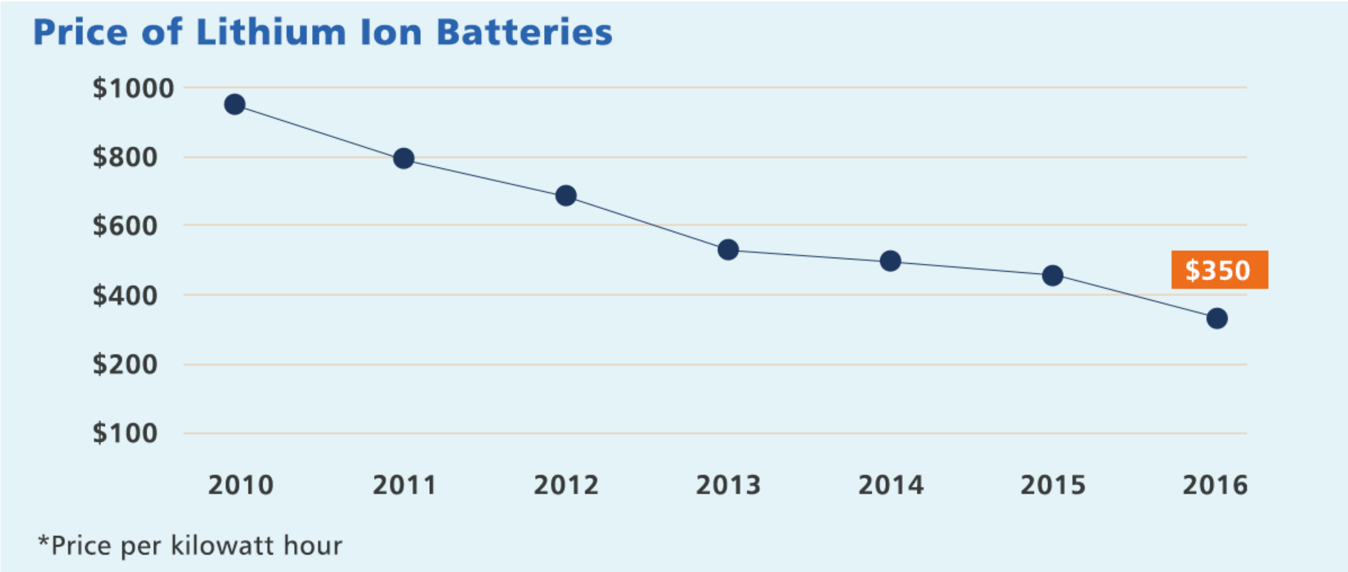
Compressed air energy storage (CAES) is a way to store energy generated at one time for use at another time. At utility scale, energy generated during periods of low energy demand (off-peak) can be released to meet higher demand (peak load) periods. Since the 1870's, CAES systems have been deployed to provide effective, on-demand energy for cities and industries. While many smaller applications exist, the first utility-scale CAES system was put in place in the 1970s with over 290 MW nameplate capacity. CAES offers the potential for small-scale, on-site energy storage solutions as well as larger installations that can provide immense energy reserves for the grid.

Thermal

Thermal energy storage technologies allow us to temporarily reserve energy produced in the form of heat or cold for use at a different time. A modern solar thermal power plant for example, produces all of its energy when the sun is shining during the day. The excess energy produced during peak sunlight is often stored in these facilities - in the form of molten salt or other materials - and can be used into the evening to generate steam to drive a turbine to produce electricity. Alternatively, a facility can use 'off-peak' electricity rates which are lower at night to produce ice, which can be incorporated into a building's cooling system to lower demand for energy during the day. A well designed thermos or cooler can storage energy effectively throughout the day, in the same way thermal energy storage is an effective resource at capturing and store energy on a temporary basis to be used at a later time.

Hydroelectric pumped storage systems

Excess or off-peak power is used to pump water from a lower reservoir to an upper reservoir, usually up a mountain. During peak demand the energy is recovered by allowing the water to flow back through turbines to produce power. The electricity produced is delivered back into the grid.



Advantages of storing power

There are two main benefits of storing energy:

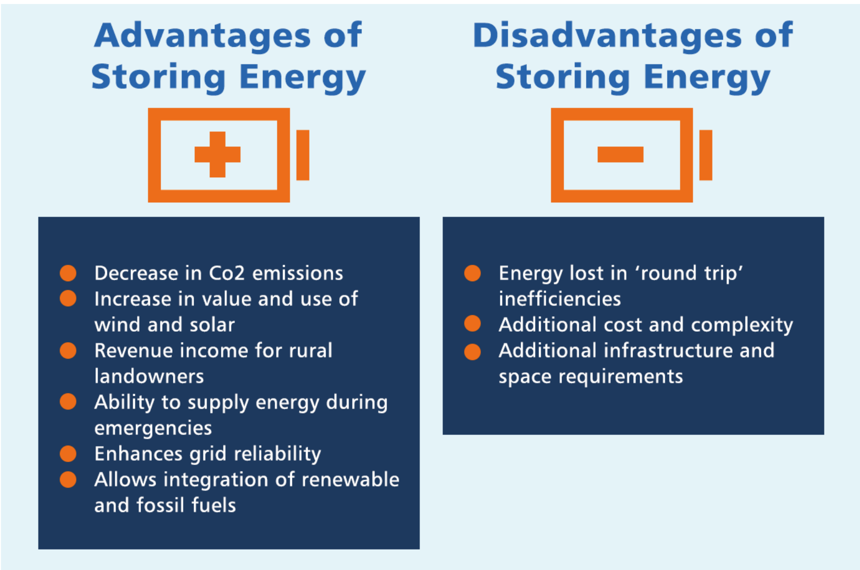
1. Avoided cost
2. Additional revenue received by the storage owner or operator

Avoided cost

There are three key forms of avoided cost. First, if storage is the only viable alternative, then avoided cost involves the negative outcomes associated with the doing nothing alternative. Next, the avoided cost for storage used in lieu of a conventional or standard solution is the cost that would have been incurred for the conventional or standard solution, including purchase, installation, operation, removal and disposal, etc. Finally, if there are several viable alternatives, then the avoided cost is the cost for the alternative with the lowest total cost.

Additional revenue

Using battery storage as an example, a versatile battery that can be used for multiple applications can generate multiple revenue streams. A simple calculation of LCOE (levelized cost of electricity) takes the total life cycle cost of a system and divides it by the system's total lifetime energy production for a cost per kWh, providing an understanding of the true value of a battery storage system.



China

China is the world's largest producer and consumer of energy and plays an important role in all global energy markets. Traditionally, growth and development in the power sector has focused on fossil fuels, especially coal. However, the focus has shifted. This is due to the continued growth in electricity demand, supply security concerns, increased attention on energy source diversification and environmental concerns. Natural gas, nuclear and renewables are now in the spotlight. Spurred by a variety of financial and government programmes, China's renewable energy capacity has grown exponentially in recent years. By the end of 2013, China had the highest installed wind capacity in the world and the second highest solar PV capacity (REN21, 2014). Given China's declared goals, the emphasis is now on additional transmission and developing storage technologies. This is because the country aims to increase wind capacity to 150 GW by 2020 (IRENA and GWEC, 2012) and solar generation capacity to 70 GW by next year. The country is concentrating on lithium-ion technology, with 101 MW of storage capacity to come from lithium-ion batteries and another 30 MW from flow battery technology. Installed projects include a 6 MWh lithium-ion-phosphate battery system in Zhangbei county provided by BYD Energy - part of the Golden Sun programme - which provides subsidies for up to 50 per cent of total solar PV system cost in both urban and rural applications (IRENA, 2014). Renewables must be connected to demand centres, and the Chinese grid must be expanded and made more flexible. Battery storage will play a role in achieving this in the short to medium term.

USA

The USA is a market leader in battery storage implementation, though installations represent a small fraction of the overall system size. Growth has been driven the country's 2009 federal stimulus package, the American Recovery and Reinvestment Act (ARRA). It is also driven by regulatory changes helping to integrate and value services provided by battery storage. Other drivers are grid reliability issues in parts of the country, state-level storage mandates and renewable support programmes. ARRA provided about USD 100 million for power sector battery storage projects, which were matched by private funds to make a total of USD 222 million towards battery storage implementation. This accounts for about 75 MW of battery storage projects, primarily for renewable energy integration and smart grid demonstration. The stimulus also encouraged the development of U.S EV manufacturing capabilities. It provided USD 2.4 billion for this purpose, a portion of which went to battery manufacturing capability (Borden and Schill, 2013; Electric Advisory Committee, 2011). In addition, constraints on generation and transmission capacity (including retiring capacity) and the integration of variable renewable energy has created grid reliability issues. This has drawn attention to the need to level the regulatory playing field and compensate non-traditional flexibility measures for the benefits they provide.

Case Studies

UK:

RES wins deal to build first battery energy storage system in UK

RES has won a contract from Western Power Distribution (WPD) to build and support its first battery energy storage system alongside British Solar Renewables 1.5MW solar park at Copley Wood in Somerset. The £1m project (€1.3m) is part of a WPD-led initiative to investigate the technical and commercial feasibility of battery energy storage combined within distributed generation installations in the UK. The engineering, procurement and construction contract will see RES build a 300kVA/640kWh project that will demonstrate nine different applications of energy storage on the grid. RES will also provide ongoing warranty support during the battery's operation and use RESolve, its energy storage control and dispatch system, to provide 24/7 management of the battery's operation. It is being delivered through Ofgem's Network Innovation Allowance, and is being run in conjunction with BSR and the National Solar Centre.

Case Studies

China:

Commissioned in 2011 in collaboration with China Electric Power Research Institute, Prudent Energy provided a 500 kW/1 MWh vanadium redox flow battery to China's Wind Power Research and Testing Centre. The battery is used to integrate the centre's 78 MW of wind and 640 kW of solar PV. It stores excess electricity during times of low demand and discharges when demand increases. The installation can also provide services over a shorter time scale, including load following and voltage support. The facility is meant to test the battery's operation. This allows the local utility, the State Grid Corporation of China, to test the technology's compatibility with China's system. The vanadium redox flow battery represents a relatively developed type of flow battery technology. It uses external tanks and pumps to store the electrolyte pumped through a cell stack during charge and discharge cycles. The systems operate at room temperature.

Ireland:

Gaelectric CAES project, Larne

Compressed Air Energy Storage (CAES) plants are largely equivalent to pumped-hydropower plants in terms of their applications, output and storage capacity. However, instead of pumping water from a lower to an upper pond during periods of excess power, in a CAES plant, ambient air is compressed and stored under pressure in an underground cavern. When electricity is required, the pressurized air is heated and expanded in an expansion turbine driving a generator for power production.

Project CAES Larne in Northern Ireland is Gaelectric's most advanced energy storage project deploying compressed air energy storage (CAES) technology. The facility will generate up to 33 MW of power for periods of up to six hours and will create demand of up to 200 MW during its compression cycle. The project has been designated as a European Project of Common Interest (PCI) and has been recommended for grant funding of up to €6.5million under the Connecting Europe Facility.

The facility will be highly responsive and will be capable of providing a range of tools to system operators in their management of the transmission grid. It has also been designed to allow its replication at other suitable sites in the United Kingdom and the European mainland.

Further reading

State of the industry report: **http://www.irena.org/documentdownloads/publications/irena_battery_storage_report_2015.pdf**

[1] Energystorage.com **http://energystorage.org/compressed-air-energy-storage-caes**