Energy Storage in the UK
An Overview

2nd Edition

RENEWABLE ENERGY ASSOCIATION

uk energy storage
EMPOWERED BY THE REA AND ITS MEMBERS

A Renewable Energy Association Publication

RENEWABLE ENERGY ASSOCIATION

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Section 1 - Introduction

The energy storage market has moved on since the first version of this REA report was published in autumn 2015, but the underlying drivers remain unchanged - a significant increase in renewable energy supplies amid growing demand for energy. At the same time, various factors are putting increasing pressure on the electricity grid network. The landmark EFR contracts (see full list in new Annex C) has kick started the large scale end of the market and turned the eyes of the world on UK energy storage providers.

Energy storage (ES) technologies offer great potential for supporting renewable energy and the UK's energy system. In 2014 the then Department for Business, Innovation and Skills (BIS) named storage as one of eight 'great technologies the UK can be world leaders in', progress has been made but clearly more action is needed to reach this potential. Many of the benefits, and possible cost trajectories for key technologies, are summarised in an REA commissioned KPMG report from early 2016 (see KPMG, 2016). Storage technologies are able to absorb and release energy when required and provide ancillary power services which help benefit the power system. The storage industry can therefore deliver tremendous benefits for system stability and security of supply as well as helping to decarbonise UK energy supplies. Storage technologies offer flexibility during times of fluctuating energy generation and demand, which make energy storage technologies an important part of a low carbon future network. In addition, there are significant economic benefits - if 2GW of energy storage was deployed by 2020 the industry could create jobs for up to 10,000 people in the UK (Strbac, et al., 2012). The landmark National Infrastructure Commission Report 'Smart Power' projected a possible £8 billion saving to the UK, per year, by 2030 if storage and flexibility measures are introduced on a large scale. This also highlights the role of energy storage as one of a range of measures for increasing flexibility.

The REA sees energy storage as a key missing piece of the UK's energy policy. Storage can help deliver the low carbon energy the country needs and it is therefore vitally important that it is appropriately incentivised and supported. The REA launched the UK Energy Storage group to help the industry reach its potential and this has now grown to over 100 member companies active across a range of technologies and scales.

Storage technologies can be deployed at different scales on a distributed and/or centralised basis. The development of energy storage technologies vary across the industry, while some are quite mature others are still in their development stages. There is significant investment in energy storage around the globe and we are now in something of a technology and deployment race. For the energy storage industry to develop and the UK to gain the huge benefits possible as a result, the Government, grid operators, industry and stakeholders need to work together to take action.

The aim of this report is to increase knowledge of the industry among various stakeholders.

This report encompasses an updated summary of the current technologies; support available internationally for storage technologies; energy storage projects deployed at present in the UK; and a discussion of the current key issues for the sector, before offering some conclusions.

This report also includes an updated list of operational UK energy storage projects (section 3.2) and successful EFR projects (Annex C) as of autumn 2016.

Benefits of Energy Storage

There are a number of benefits energy storage can offer in various forms and to various stakeholders, these include;

- Energy storage can enable the integration of more renewables (especially solar PV and wind) in the energy mix.
- Storage technologies could decrease the need to invest in new conventional generation capacity, resulting in financial savings and reduced emissions especially from electricity generation.
- Storage technologies improve our energy security by optimising the supply and demand, thus reducing the need to import electricity via interconnectors.
- They can also provide system stability during electricity outages by supplying energy at these times and reducing the financial costs of power outages.
- Utilisation of storage also means fewer and cheaper electricity transmission and distribution system upgrades are required.
- Energy can be stored when prices are low and used on site when they are high to save consumers and businesses money on their bills. Alternatively the stored energy can be sold.
- Large amounts of energy storage can significantly reduce energy loss during transmission and distribution. Electricity transmission losses typically run at just below 10% of the total energy first produced in the UK (this is formalised in the UK by the application of a transmission loss multiplier to CfD generation of 9%).
- Storage can provide ancillary services to the System Operator at lower cost, lower carbon intensity than traditional providers such as conventional thermal power plants.
- Storage technologies can reduce the usage of fossil fuels, enabling a greener, lower carbon energy supply mix.

Section 2 - Energy Storage Technologies

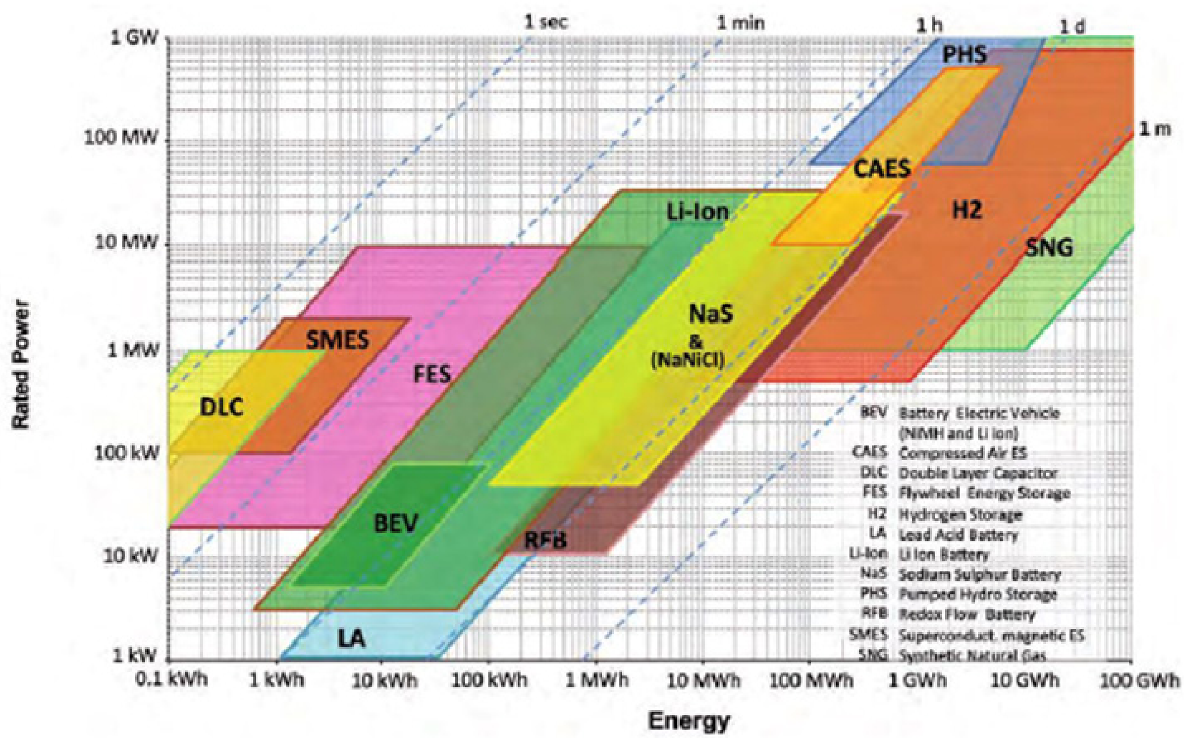


Figure 2-1 Overview of energy storage technologies, power and energy storage durations (IEC, 2011)

Energy storage technologies are classified according to the form of energy they use. This section provides short overviews of each technology, using explanations from different sources presented in order to be comparable to each other, (please note that new technologies are being developed, however this report necessarily covers only those that are widely used, deployed or close to deployment).

2.1 Mechanical

2.1.1 Pumped hydro storage (PHS)

Pumped hydro, one of the most mature energy storage technologies, stores energy by using off-peak electricity to pump water from a lower reservoir to an upper reservoir. It recovers energy by allowing the water to flow back through turbines to produce power. As of 2015, there is 143 GW of installed capacity worldwide, which represents around 95% of total global capacity (Yang, 2014). The technology is reliant on topographical features for its deployment but significant potential still exists in the UK.

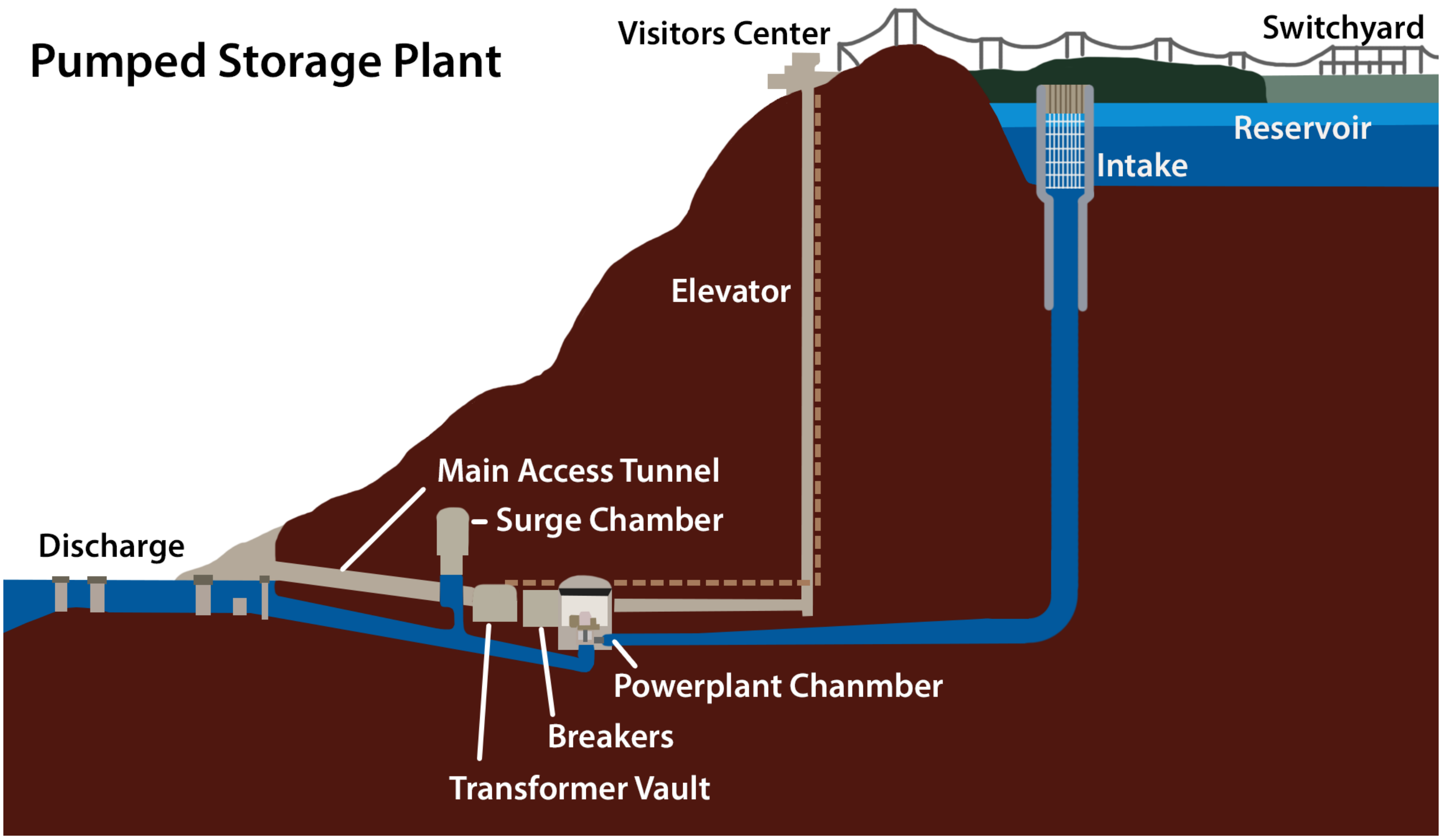


Figure 2-2 Illustration of a Hydroelectric Pumped-Storage System

2.1.2 Compressed air energy storage (CAES)

Compressed air energy storage (CAES), stores energy either in an underground structure or an above-ground system, by running electric motors to compress air and then releasing it through a turbine to generate energy. It can help the grid by storing energy during low demand (off-peak) and then releasing it during high-energy demand (peak load) periods. CAES technology has large capacity but the main issues with it are relatively low round-trip efficiency and geographic location limitations. Although it consumes energy in the process overall, it creates around three times the energy a similar sized conventional gas turbine would produce.

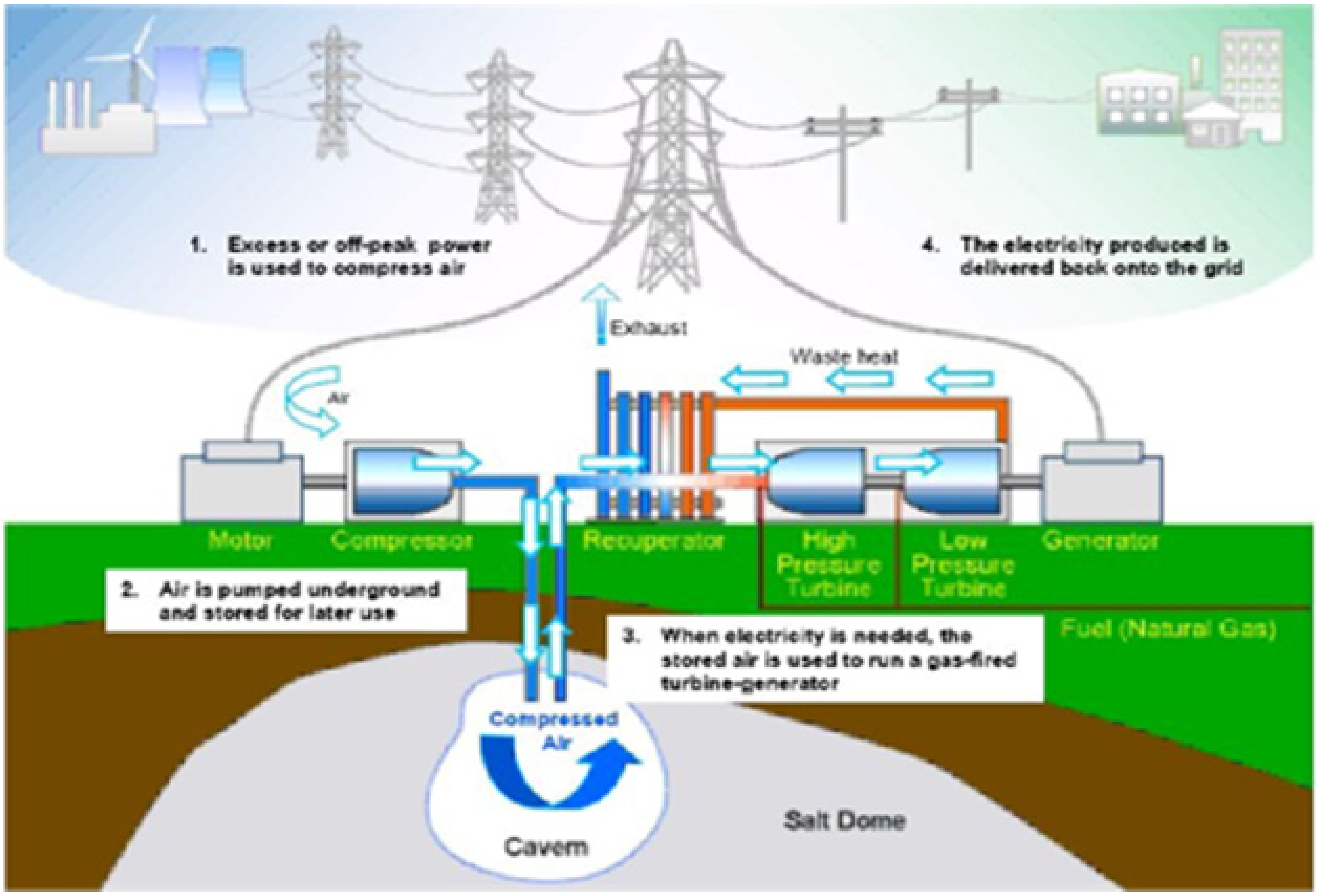
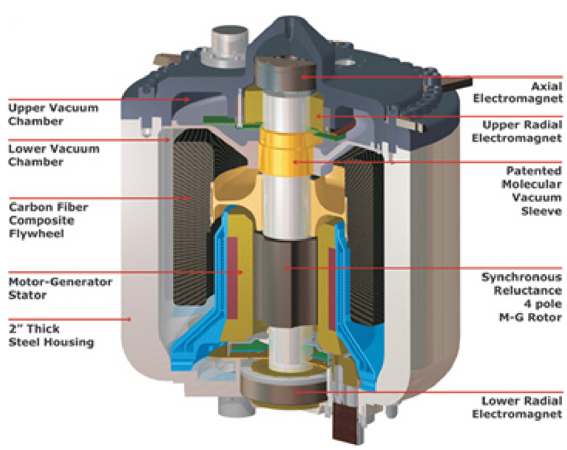


Figure 2-3 Underground CAES technology (Ridge Energy Storage & Grid Services L.P., 2015)

2.1.3 Flywheels

Flywheels are charged by accelerating the inertial masses also known as the rotors. The energy is stored as the rotational kinetic energy of the flywheel. To discharge the kinetic energy it is extracted by a generator, which decelerates the rotation. Flywheels have good cycle stability, a long life cycle, are low maintenance, high power density and use environmentally inert materials. At the same time, they currently have relatively low efficiency and high levels of self-discharge. Flywheels are commercially deployed and developments are underway to increase their use in vehicles and power plants (IEC, 2011).



2.2 Electrochemical energy storage (batteries)

2.2.1 Conventional batteries

Batteries offer an established form of energy storage both as a standalone option and some can be used after use in Electric Vehicles as a ‘second life’ storage option in domestic and commercial settings.

Lead Acid
The most mature of the battery technologies, used commercially since the 1890’s. Lead acid batteries, despite their toxicity, are very popular due to low cost/performance ratio, short life cycle, simple charging technology and low maintenance requirements. Their main disadvantage is that as they discharge higher power their usable capacity decreases. Other disadvantages include a relatively low energy density.

Nickel-Cadmium (NiCd)
A mature technology, used since around 1915, nickel cadmium batteries have low round trip efficiency, high energy density and a long life cycle. They can perform well at low temperatures ranging from -20 °C to +40 °C. The batteries are highly toxic which is why they are used only for stationary purposes in Europe. There are about 32 MW of NiCd batteries installed globally (DoE, 2016).

Lithium-Ion
The most well-known and widely used in consumer electronics, lithium-ion batteries have high energy density, low standby losses and a tolerance to cycling. There are many different applications, however the most popular at the moment is their application in Electric Vehicles. They are very flexible in their discharge time, which can be realised from seconds to weeks. Although prices are still considered to be relatively high, they have started to come down in price, and it is projected that this trend will continue in future years. A relatively new technology but likely to be widely deployed in the short term.

Figure 2-5 Artist's impression of a grid storage system to be tested at a wind farm in China (A123 Systems, 2015)

2.2.2 High temperature batteries

High temperature batteries are similar to conventional batteries but differ because their energy is based on reactions that only occur at elevated temperatures (ECOFYS, 2014). The most frequently used are sodium sulfur (NAS) and sodium nickel chloride (NaNiCl).

Sodium Sulfur (NAS)
Still in the early stages of currently grid. Deployed at grid scale in Japan, NAS batteries are used for long durations of energy storage, they have high round-trip efficiency, relatively high energy density but their costs continue to be high.

Sodium Nickel Chloride (NaNiCl)

The sodium nickel chloride battery is a high-temperature battery which has been commercially available since 1995. These batteries can stand limited overcharge and discharge. They have been used in electric vehicles (EVs) and new research is being done to further develop these batteries and use them in alternative settings following the end of their productive life in EVs.

Copper/Zinc Rechargeable Battery (Cu/Zn)

Cumulus Energy Storage (CES) have recently developed a rechargeable Cu/Zn battery, combining a 200-year old battery technology with processes from the mining industry. Although still developmental, rechargeable Cu/Zn batteries provide a large scale storage option, capable of delivering grid-scale levels of power from 1MWh to 100MWh. These batteries are stationary, with potential applications including time-shifting for commercial renewable electricity generation and security and stability of supply. Main advantages of this technology are its low cost, simplicity, scalability and sustainability. The batteries are low maintenance with a long target lifecycle of 30 years. Pilot line production capacity is expected by the end of 2016 in the UK. (CES, 2015)

2.2.3 Flow batteries

The electrochemical reactions of flow batteries are similar to conventional and high temperature batteries, but their storing techniques differ. The electrolytes used are stored in external tanks and during charge and discharge they are pumped through electrochemical cells, which convert chemical energy into electricity. The most well-known types of flow batteries are redox and hybrid.

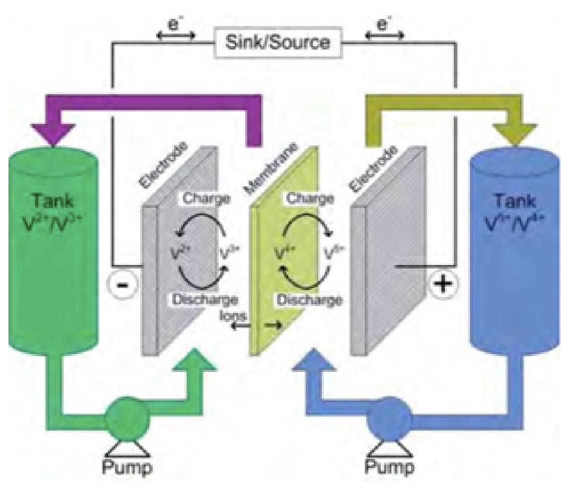


Figure 2-6 Vanadium Redox Flow Battery (Schwunk, 2011)

Redox Flow Battery (RFB)

Redox flow batteries are similar to conventional batteries except when the battery is discharged the fluids need to be newly-loaded. The electrolyte volume and power, which are related to the electrode area in the cells, determine the energy of the batteries. These batteries have a high level of discharge but low energy density although they have reached commercialisation. They are suitable for mobile application in theory, however, until now their energy densities have been too low for this type of application. Two common redox flow battery chemistries are **zinc bromine** and **vanadium**.

2.3 Chemical energy storage

Chemical energy storage technology, by using hydrogen and synthetic natural gas (SNG), relies on electric energy to generate fuel that may be burned in conventional power plants. By using water electrolysis the water is split into hydrogen and oxygen. The hydrogen can either be burned directly or it can be transformed to SNG. The efficiency of this technology is lower compared to PHS and Lithium-ion batteries. However, it remains an important technology because it allows large amounts of energy to be stored over longer periods of time.

Hybrid Flow Battery (HFB)
Hybrid flow batteries on the other hand use electro-active components deposited as a solid layer. (ECOFYS, 2014) The active masses are stored separately; one is stored internally in the electrochemical cell and the other externally in a tank. They are called hybrid because they bring properties from conventional secondary batteries and from redox batteries. A number of companies are working on commercializing Zn-Br hybrid flow batteries on utility-scale applications and in community energy storage systems (IEC, 2011).

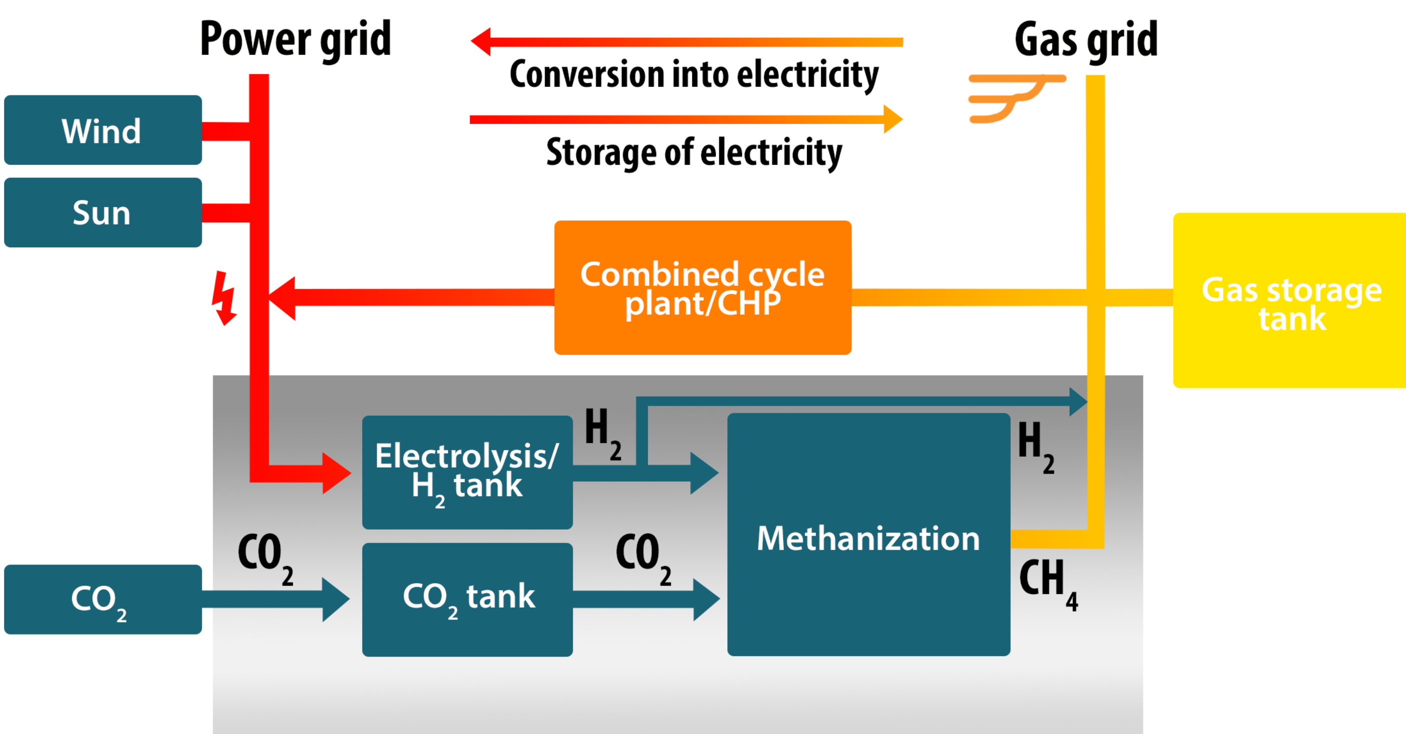


Figure 2-7 Schematic overview of chemical energy storage (power-to-gas) system

2.3.1 Hydrogen (H_2)

There are different hydrogen storage techniques however the most popular is storing the gas under high temperatures used mainly for stationary applications. Smaller amounts can be stored above ground, in tanks or bottles, and large amounts stored underground mainly in piping systems. This technology is being examined closely for industrial applications and is not yet used commercially in a widespread way.

2.3.2 Synthetic natural gas (SNG)

Synthetic gas processes are referred to as “Power to Gas” technologies. After splitting water another step is added to the mix and with the help of an electrolyser the hydrogen and carbon dioxide react to generate methane. SNG can also be stored in over-ground pressure tanks, underground or can be directly injected into the gas grid. The most important advantage of synthetic methane is that it can be injected into the existing natural gas storage infrastructure without restrictions. However, on the other hand it has relatively low efficiency. (ECOFYS, 2014)

2.4 High temperature thermal energy storage

There are a number of thermodynamic energy storage technologies in development and operational - notably thermal energy storage, high temperature thermal energy storage, pumped heat electrical storage and liquid air energy storage.

2.4.1 Thermal energy storage (TES)

There are three main types of TES - sensible heat storage, latent heat storage and thermo-chemical storage.

2.4.2 Sensible heat storage

These technologies store heat in a solid or liquid, without any change of state. These are widely used for domestic systems, district heating and industrial needs through electric storage heaters and hot water tanks. Common materials used include water, sand, molten salt and rocks, with water the most cost-effective. While this is the cheapest of the three TES technologies, capacity is subject to spatial restrictions and materials can have low energy density.

2.4.3 Latent heat storage

Latent heat storage stores energy using materials with high latent heat, known as phase change materials (PCMs). PCMs store energy as they change state, usually from solid to liquid. This technology has higher storage capacities and target-oriented discharging temperatures.

2.4.4 Thermo-chemical storage

This storage technology uses chemical reactions such as absorption to store and release thermal energy, as well as to control humidity. Thermo-chemical storage systems are highly efficient, with high energy density.

2.4.5 High temperature thermal energy storage

This technology is used to store heat above 250°C from concentrating solar facilities. Adding this technology to existing or future solar thermal power plants may present flexibility options in order to be able to feed the power into the grid at times of no sunshine. However, for widespread deployment control technology, containment mediums and material stability need to be improved for high temperatures and such plants do not exist in the UK at scale nor are expected to in the future.

2.4.6 Pumped heat electrical storage

One technique is pumped heat electrical storage, which transfers heat loads between a 'cold' store and a 'hot' store, acting like a fridge. A heat pump is used to transfer the heat between stores, recovering the energy as it pumps between the two; chemicals with particular qualities are used to enable the process. This is still in the development phase but commercial plants are expected in the next year or two.

2.4.7 Liquid air energy storage (LAES)

Also known as Cryogenic Energy Storage (CES), LAES uses electricity to cool purified air until liquefied and then stores the liquid air at low pressures in a large insulated tank. When the stored energy is required, the liquid air is pumped to high pressure and vaporised before being heated and expanded to drive a turbine. LAES consequently provides large scale, long duration energy storage with no geographical constraints. Although requiring electrical energy to cool and heat the air, waste heat/cold from other industrial processes can be used to increase efficiency.

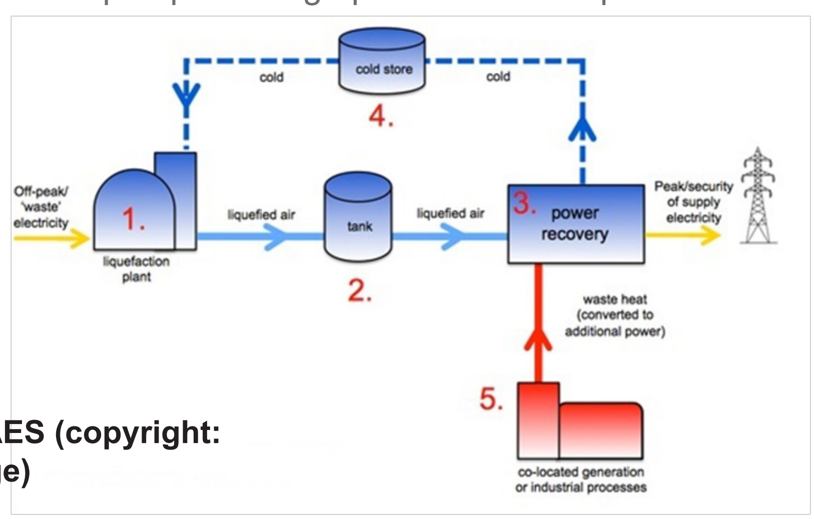


Figure 2-8 Schematic diagram of LAES (copyright: Highview Power Storage)

2.5 Electromagnetic

2.5.1 Capacitors

Capacitors, also known as double-layer or supercapacitors, are related to classical capacitors used in electronics and general batteries. (IEC, 2011) Since the 1980's they have been used in a variety of consumer and power electronics. They have potential because they have extremely high capacitance value as well as the possibility of fast charge and discharge. They are very durable, reliable, need very little maintenance, have a long life cycle and can operate in different temperatures. However, they are interdependent on cells, are sensitive to cell voltage imbalances and maximum voltage thresholds, and may raise safety concerns.

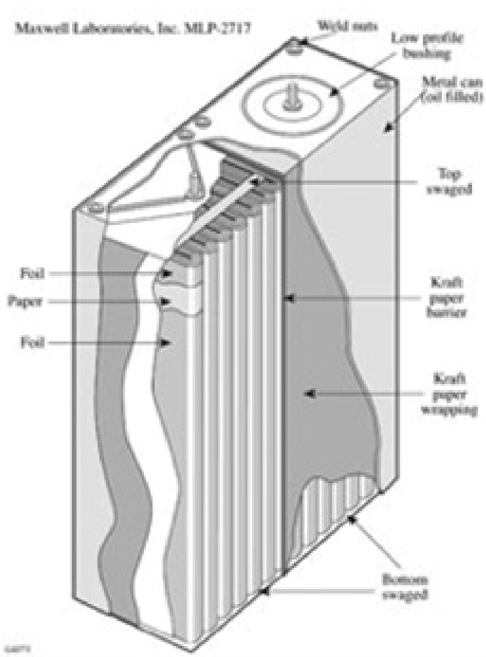


Figure 2-9 Cutaway view of a PCU energy storage capacitor (Rochester Laboratory for Laser Energetics, 2015)

2.5.2 Superconducting magnetic energy storage (SMES)

This technology stores energy by using the flow of direct current through a cryogenically cooled superconducting coil to generate a magnetic field that stores energy (ECOFYS, 2014). Once the superconducting coil is charged and has reached a steady state the inductor where energy is stored does not dissipate, the current will not deteriorate and the magnetic energy can be stored almost indefinitely. The stored energy is released by discharging the coil. The technology is still in its development stage. SMES has a high life cycle and rapid response but on the other hand has a relatively low energy density, high cost and requires constant cryogenic refrigeration in order to maintain superconducting properties.

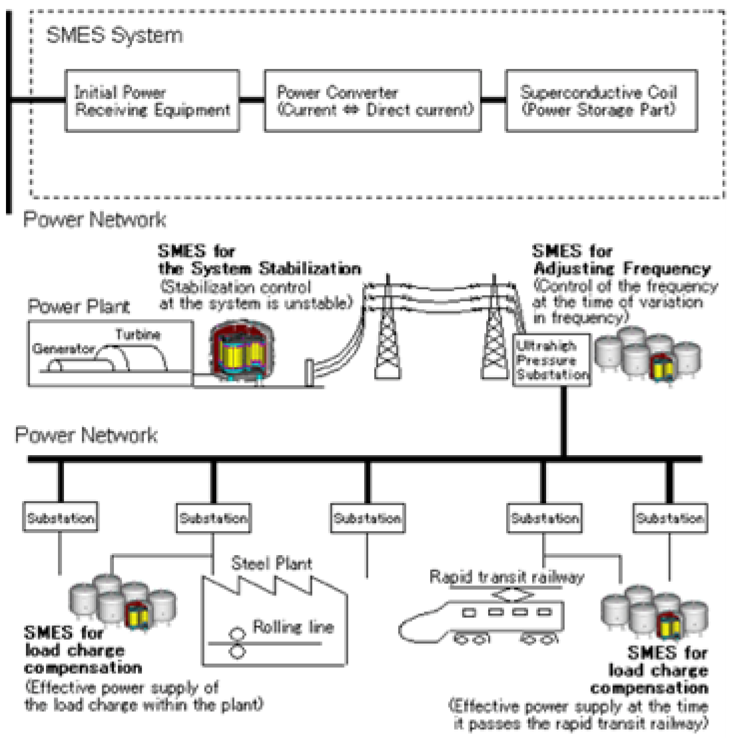


Figure 2-10 An example of the composition of a SMES for electric power generation (Chubu Electric Power Co Inc., 2007)

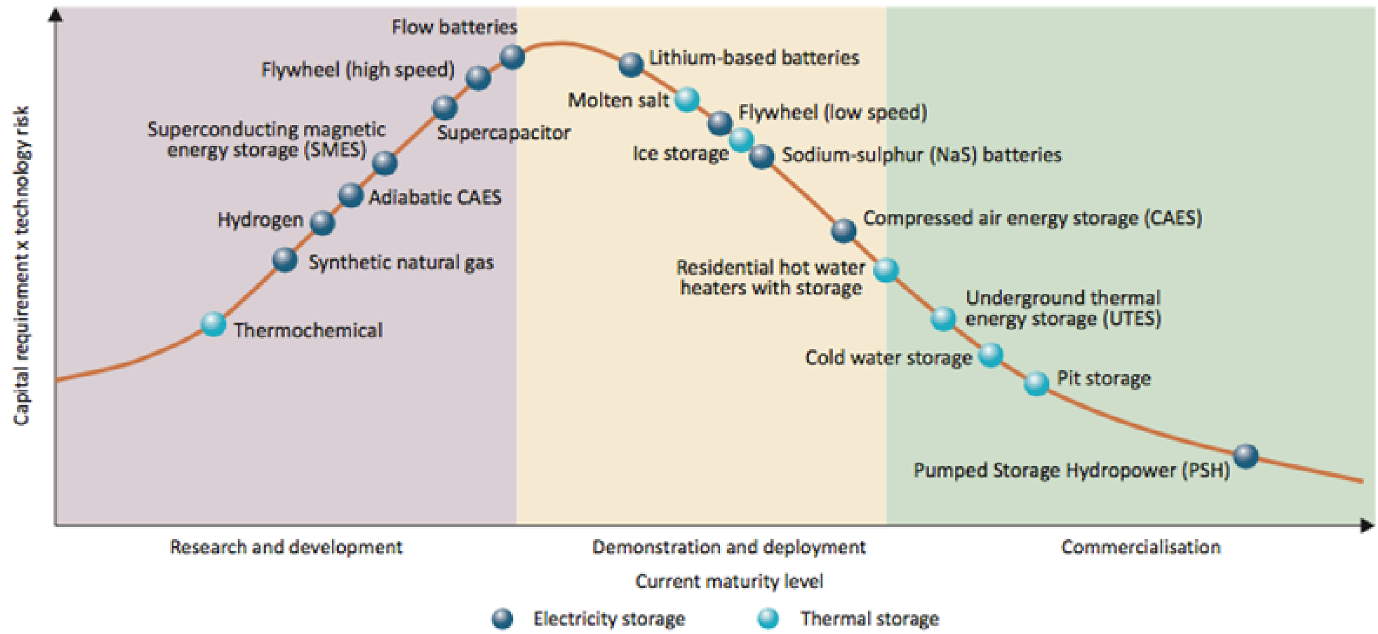


Figure 2-11 Approximate maturity of energy storage technologies (IEA, 2014)

Table 2-1 Cost and efficiency of storage technologies (ECOFYS, 2014 and REA Research) - Costs in 2010 US dollars

Technology	Maturity	Power cost ($/kW)	Energy cost ($/kWh)	Efficiency	Cycle limited	Response time
Pumped Hydro	Mature	1,630-2,930	150-370	80-82%	No	Seconds to Minutes
Compressed Air (Underground)	Demo to Mature	1,040-1,360	65-160	60-70%	No	Seconds to Minutes
Compressed Air (Above ground)	Demo to Deploy	2,120-2,335	420-470	60-70%	No	Seconds to Minutes
Flywheels	Deployed to Mature	2,120-2,390	420-470	85-87%	>100,000	Instantaneous
Lead Acid Batteries	Demo to Mature	1,030-6,300	380 – 4,130	75-90%	2,200->100,000	Milliseconds
Lithium-ion batteries	Demo to Mature	1,180-4,450	975 – 6,740	87-94%	4,500->100,000	Milliseconds
Copper zinc batteries	Develop to Demo	-	-	~80%	Thousands of cycles	Milliseconds
Flow Batteries (Vanadium Redox)	Develop to Demo	3,260-4,020	675 - 900	65-75%	>10,000	Milliseconds

Sodium Sulfur (NAS)	Demo to Deploy	3,370-4,345	480 - 600	75%	4,500	Milliseconds
Power to Gas	Demo	1,490-2,975	-	30-45%	No	10 Minutes
High Temperature Thermal Storage	Demo to Deploy	-	-	~30%	No	**Storing**: Seconds; **Generating**: Minutes
Capacitor	Develop to Demo	-	-	90-94%	No	Milliseconds
SMES	Develop to Demo	-	-	95%	No	Instantaneous
LAES/CES	Demo to Deployment	$1,000	150 - 450 (depending on scale)	~60%	No	2 to 5 minutes
TES	Development to Mature	-	0.5 – 100 (depending on technology)	50-99.9%	No	Minutes

Section 3 - Energy Storage Today

3.1 Energy storage policies internationally

Many countries and regions have recognised the potential of energy storage technologies and have developed policies to deploy energy storage at different scales

Table 3-1 Examples of international government action to support energy storage

Country or Region	Organisation and Overview
Canada	**Ontario Ministry of Energy** • In 2013, the government released a Long-Term Energy Plan, which included procurement target of 50 MW for storage technologies. The LTEP has targets of 10,700 MW of wind (11%), solar (3%) and bioenergy (3%) by 2021 (each source representing their percentage of total energy production).
China	**Central Government** • There have been funding for demonstration projects such as the Zhangbei project in Hebei, which has 36 KWh lithium-ion battery capacity, in order to evaluate the value energy storage would have when providing electricity gird flexibility. • The National Energy Administration (NEA) is expected to release 13 energy policies in 2015, which include large capacity energy storage and EV charging infrastructure. • It is anticipated in 2015 that the National Reform and Development Commission will implement time-of-use pricing mechanisms.

European Union	**European Commission - Framework Research Programme** • The 'stoRE' project, co-funded by the Intelligent Energy Europe Programme of the EU, aims to create a framework that will allow energy storage infrastructure to be developed in support of higher penetration of variable renewable energy resources. Target countries to identify a series of improvements/application include, Austria, Denmark, Germany, Greece, Ireland and Spain. **Proposed - European Commission - Winter Package (publication due winter 16/17)** • As of autumn 2016 discussions regarding the EC's 2016/17 'Wonter Package' of legislation included proposals for an energy storage definition
Germany	**Federal Ministry of the Environment, Nature Conservation and Nuclear Safety** • Since May 2013, part of the support scheme for solar-plus-batter, the state-owned bank Kreditanstalt für Wiederaufbau (KfW) has granted low interest loans with an aggregate value of €163 million for 10,000 energy storage projects combined with PV installations with a power up to 30 kW. • The Ministry also covers 30% of the storage system costs. Eligible PV systems should feed maximum 60% of installed capacity into the grid.
Japan	**Ministry of Economy, Trade and Industry** • Government support to demonstrate the ability to time-shift demand by 10% in conjunction with expanded use of renewable generation resources. Within the next seven years METI funding is aiming to decrease the total cost by providing funds up to 75% of the total storage system cost. • METI is planning to spend around 81 billion yen to resolve grid related issues and to increase renewable energy. Additionally, the Ministry is aiming to provide incentives for energy storage systems, which can be implemented onto solar power stations or substations. The budget is awaiting parliament approval. **Ministry of Environment** • Up to 50% subsidy for storage battery for renewable energy generation (<1MW) • Subsidy for renewable energy in local areas (Total 1bn JPY)
South Korea	**Ministry of Trade, Industry, and Energy (MOTIE)** • Customised electric rates to stimulate the energy storage system and electric vehicle industries along with drawing investment in storage and the use of eco-friendly EVs by consumers (MOTIE, 2015). • The government plans to install 500kWH of energy storage systems. The Korea Electric Power Corporation also plans to install 1000kWh of storage (Agency for Growth Policy Analysis, 2014). • MOTIE also supports small and mid-sized companies with various incentives to install energy storage systems. **Central Government** • President Park has expressed support for innovative energy systems, which includes the usage of ES within Energy Management Systems and smart grids.
United States	**Proposed – S. 3159 – Energy Storage Tax Incentive and Deployment Bill 2016** • The bill introduced in July 2016 would make energy storage systems with a capacity of at least 5 kWh investment tax credit eligible, regardless of whether the power was supplied by a renewable resource. • The bill would also allow individuals to own a storage system with a capacity of at least 3 kWh used at their homes and to claim a residential energy efficient property tax credit. Like the proposed ITC rules for storage, an individual could qualify for the credit even if the storage system was unrelated to a solar system. • The progress of the Bill could depend on being combined with other related tax proposals to speed it's adoption.

Storage Technology for Renewable and Green Energy Act of 2013 or the Storage 2013 Act

- Similar to the Storage Act of 2011 this act promotes deployment of energy storage technologies by recognising the benefits for renewables and consumers and benefits to the grid. The Act aims to level the playing field of energy tax incentives (U.S. Senate Committee, 2013).
- The Act provides 20% investment tax credit of up to $40 million per project connected to the electric grid and distribution system. Additionally, the Act provides 30% investment tax credit of up to $1 million per project to businesses for on-site storage (ibid).
- An important change from the Act of 2011 is that the minimum size of system eligibility had been lowered from 20kWh to 5kWh. This change helps promote deployment of systems from small businesses to the grid and it is expected to incentivise storage companies to create leasing models for residential users (ibid).
- The Act also provides 30% tax credit for homeowners for on-site storage systems to store off-peak electricity from solar panels or from the grid for later use (ibid).

Federal Energy Regulatory Commission (Orders)

- Order 755 increases the pay for "fast" responding sources like batteries or flywheels that are bidding into frequency regulation service markets. "Fast-ramping, more accurate resources are now given greater compensation in the wholesale frequency regulation markets" (DOE, 2015). The FERC is ensuring that it's providing just and reasonable and not unduly discriminatory or preferential rates of frequency regulation.
- Order 784 expands Order 755 and focuses on third-party provision of ancillary services and accounting and financial reporting for new electric storage technologies (ibid). According to the Order public utilities must take into account the speed and accuracy of regulation resources, which opens the door for greater efficiency in transmission customers' purchase of regulation resources. Additionally, the order eases the barriers for third-party entry into ancillary service markets and by revising accounting and reporting requirement to improve market transparency.
- The incentives for systems that provide summer on-peak demand reduction are $2,600/kW for thermal storage and $2,100/kW for battery storage technologies (ibid). Proposed incentives are capped at 50% of installed project cost plus bonus incentives are available for large (>500kW) projects.

Master Limited Partnerships Parity Act

- A Master Limited Partnership (MLP) "is a business structure that is taxed as a partnership, but whose ownership interests are traded like corporate stock on a market" (Library of Congress, 2013). However, it has only applied for fossil fuel-based energy partnerships within the internal revenue code.
- The MLP Parity Act "Amends the Internal Revenue Code, with respect to the tax treatment of publicly traded partnerships as corporations, to expand the definition of "qualifying income" for such partnerships to include income and gains from renewable and alternative renewable fuels and chemicals, energy efficient buildings, gasification, and carbon capture in secure geological storage" (Lib. of Cong., 2013).
- The MLP Parity Act expands MLP eligibility to an array of renewable energy sources, including "electricity storage devices" (DOE, 2015). If the Act is enacted, it will allow for more equitable taxation methods across all energy sectors, and will allow for new ownership and taxation models for energy storage device partnerships (ibid).
- MLP Parity Act was introduced in 2012 and then in 2013 (with expanded qualifying resources) and still awaits approval.

3.2 UK energy storage projects

There are currently 39 installed stand-alone energy storage projects in the UK, as detailed in the table below.

Project Name	Location	Technology Category	Technology Type	Rated Power in kW	Capacity in kWh	Status	Commissioning Date	Decommissioning Date	Service/Use Case 1	Service/Use Case 2	Service/Use Case 3	Service/Use Case 4
ABB & UK Power Networks Energy Storage Installation	Hemsby, Norfolk	Electro-chemical	Lithium-ion Battery	200	200	Operational	19.05.2011	01.08.2016	Voltage Support	Distribution upgrade due to wind	Renewable Energy Time Shift	Electric Supply Reserve Capacity - Spinning
AES Kilroot Station Battery Storage Array	Carrickfergus, Northern Ireland	Electro-chemical	Lithium-ion Battery	10000	5000	Operational	01.02.2016		Frequency Regulation			
Anesco UK Berkshire Farm System	Berkshire, England	Electro-chemical	Lithium-ion battery	250	250	Operational	23.06.2015		Onsite Renewable Generation Shifting	Renewable Capacity Firming	Resiliency	
Cruachan Power Station	Lochawe, Dalmally	Pumped Hydro Storage	Open-loop Pumped Hydro Storage	440000	9,680,000	Operational	15.10.1965		Electric Supply Reserve Capacity - Spinning	Electric Energy Time Shift	Electric Supply Capacity	Load Following (Tertiary Balancing)
Dinorwig Power Station	Dinorwig, Wales	Pumped Hydro Storage	Closed-loop Pumped Hydro Storage	1728000	8,640,000	Operational	01.01.1984		Electric Supply Reserve Capacity - Spinning	Electric Supply Capacity	Electric Energy Time Shift	Frequency Regulation
Eastheat - Local Energy Challenge Fund homes fitted with SunampPV	Edinburgh, East Lothian, Midlothian, West Lothian, Clackmannanshire	Thermal Storage	Phase Change Material Heat Battery	24255		Operational	42460		Onsite Renewable Generation Shifting	Electric Energy Time Shift	PV Self-Consumption	Provision of Domestic Hot Water
Eastheat - SunampStack at Newcarron Court	Falkirk	Thermal Storage	Phase Change Material Heat Battery	630		Operational	42460		Thermal & Electric Energy Time Shift	MicroCHP with Heat Pump Charging	District Heating	Provision of Domestic Hot Water
EFDA JET Fusion Flywheel	Abingdon, Oxfordshire	Electro-mechanical	Flywheel	400000	5560	Operational	01.01.2006		On-Site Power	Frequency Regulation		
Grid Connected Energy Storage	Willenhall, West Midlands	Electro-chemical	Lithium Ion Titanate Battery	2000	1000	Operational	17.03.2016		Frequency Regulation	Commercial (Reliability &		
Ffestiniog Pumped Hydro Power Plant	Ffestiniog, Gwynedd	Pumped Hydro Storage	Closed-loop Pumped Hydro Storage	360000	2,160,000	Operational	31.12.1963		Electric Energy Time Shift	Electric Supply Capacity		
Flat Holm Microgrid Project	Flat Holm Island, Wales	Electro-chemical	Lead-acid Battery	5	25	Operational	01.06.2006		Electric Supply Capacity	Onsite Renewable Generation Shifting	Renewable Energy Time Shift	
Foula Community Electricity Scheme	Isle of Foula, Highland Scotland	Electro-chemical	Lead-acid Battery	16	80	Operational	01.03.2007		Onsite Renewable Generation Shifting	Renewables Energy Time Shift		
Foyers Pumped Storage Power Station	Loch Ness, Highland	Pumped Hydro Storage	Open-loop Pumped Hydro Storage	300000	n/a	Operational	31.12.1974		Electric Energy Time Shift	Electric Supply Capacity		
Gaelectric Compressed Air Energy Storage (CAES) System	Larne, County Antrim	Electro-mechanical	In-ground Compressed Air Storage	330000	1,980,000	Announced	31.12.2017		Electric Energy Time Shift	Renewable Capacity Firming	Renewable Energy Time Shift	
Gigha Wind Farm Battery Project	Gigha, Scotland	Electro-chemical	Vanadium Redox Flow Battery	100	1260	Contracted			Renewable Energy Time Shift	Renewable Capacity Firming		
Highview Pilot Plant	Slough, Berkshire	Electro-mechanical	Liquid Air Energy Storage	350	2450	Decommissioned and transferred to Birmingham	31.07.2011	31.12.2014	Renewable Energy Time Shift	Electric Energy Time Shift	Renewable Capacity Firming	Electric Bill Management
Horse Island Microgrid Project	Horse Island, Scotland	Electro-chemical	Lead-acid Battery	12	60	Operational	01.08.2009		Renewable Capacity Firming	Electric Supply Capacity	Onsite Renewable Generation Shifting	
Isentropic Demonstration Project	Toton, Nottinghamshire	Thermal Storage	Heat Thermal Storage	1400	5600	Announced			Stationary Transmission/Distribution Upgrade Deferral	Renewable Energy Time Shift	Electric Energy Time Shift	Voltage Support
Isle of Eigg Electrification Project	Isle of Eigg, Scotland	Electro-chemical	Lead-acid Battery	60	220	Operational	01.02.2008		Onsite Renewable Generation Shifting	Electric Supply Capacity	Frequency Regulation	Voltage Support

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Project Name	Location	Technology Category	Technology Type	Rated Power in kW	Capacity in kWh	Status	Commissioning Date	Decommissioning Date	Service/Use Case 1	Service/Use Case 2	Service/Use Case 3	Service/Use Case 4
Isle of Muck Microgrid System	Isle of Muck, Scotland	Electro-chemical	Lead-acid Battery	45	165	Operational	01.03.2013		Onsite Renewable Generation Shifting	Electric Supply Capacity		
Isle of Rum Microgrid System	Isle of Rum, Scotland	Electro-chemical	Lead-acid Battery	45	165	Operational			Onsite Renewable Generation Shifting	Electric Supply Capacity	Renewable Energy Time Shift	
Northern Isles New Energy Solution (NINES)	Lerwick, Shetland Isles	Electro-chemical	Sodium-sulfur Battery	1000	3000	Under Construction	01.03.2014		Renewables Energy Time Shift	Renewable Grid Integration		
Northern Powergrid CLNR EES1	Rise Carr, Darlington	Electro-chemical	Lithium-ion Battery	2500	5000	Operational	01.09.2013		Voltage Support	Electric Energy Time Shift	Stationary Transmission/Distribution Upgrade Deferral	
Northern Powergrid CLNR EES3-2	Wooler, Northumberland	Electro-chemical	Lithium-ion Battery	50	100	Operational	01.09.2013		Voltage Support	Electric Energy Time Shift	Stationary Transmission/Distribution Upgrade Deferral	
Northern Powergrid CLNR ESS2-1	Rise Carr, Darlington	Electro-chemical	Lithium-ion Battery	100	200	Operational	01.09.2013		Voltage Support	Electric Energy Time Shift	Stationary Transmission/Distribution Upgrade Deferral	
Northern Powergrid CLNR ESS2-2	Denwick, Northumberland	Electro-chemical	Lithium-ion Battery	100	200	Operational	01.09.2013		Voltage Support	Electric Energy Time Shift	Stationary Transmission/Distribution Upgrade Deferral	
Northern Powergrid CLNR ESS3-1	Rise Carr, Darlington	Electro-chemical	Lithium-ion Battery	50	100	Operational	01.09.2013		Voltage Support	Electric Energy Time Shift	Stationary Transmission/Distribution Upgrade Deferral	
Northern Powergrid CLNR ESS3-3	Malby, South Yorkshire	Electro-chemical	Lithium-ion Battery	50	100	Operational	01.09.2013		Renewable Capacity Firming	Renewables Energy Time Shift	Stationary Transmission/Distribution Upgrade Deferral	Transmission upgrades due to solar
Orkney Storage Park Project	Kirkwall, Orkney	Electro-chemical	Lithium-ion Battery	2000	500	Operational	01.06.2013		Transmission Congestion Relief			
QBC Glyn Rhonwy Pumped Storage Project	Snowdonia, North Wales	Pumped Hydro Storage	Pumped Hydro Storage	49900 and undergoing consultation for up to 99900	600,000	Announced	01.01.2018		Electric Energy Time Shift	Electric Supply Capacity		
redT Wokingham Development Facility	Wokingham, Berkshire	Electro-chemical	Vanadium Redox Flow Battery	5	40	Operational	15.10.2015		Electric Energy Time Shift	Renewables Energy Time Shift		
RES Battery Energy Storage System with BSR and WPD	Butleigh, Somerset	Electro-chemical	Lithium-ion and Lithium Iron Phosphate Battery	640	640	Announced	01.01.2018		Electric Bill Management with Renewables	Renewable Capacity Firming	Renewable Energy Time Shift	
Slepe Farm Storage System	Dorset, England	Electro-chemical	Lithium-ion Battery	598	249	Operational	10.10.2014		Electric Supply Reserve Capacity - Spinning	Onsite Renewable Generation Shifting	Renewable Capacity Firming	
Slough Zero-Carbon Homes Community Energy Storage	Slough, Berkshire	Electro-chemical	Lithium-ion Battery	75	75	Operational	01.05.2012		Renewable Energy Time Shift	Renewable Capacity Firming		
Smarter Network Storage	Leighton Buzzard, Bedfordshire	Electro-chemical	Lithium-ion Battery	6000	10,000	Operational	12.12.2014		Electric Energy Time Shift	Electric Supply Reserve Capacity - Non-Spinning	Frequency Regulation	Stationary Transmission/ Distribution Upgrade Deferral
SOLA Bristol	Knowle West, Bristol	Electro-chemical	Lead-acid Battery	100	279	Decommissioned	01.12.2011	01.01.2016	Electric Energy Time Shift			
University of Birmingham Cryogenic Energy Storage (CES) Pilot	Birmingham, West Midlands	Electro-mechanical	Liquid Air Energy Storage	350	2500	Operational	11.12.2015		Electric Energy Time Shift			

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Project Name	Location	Technology Category	Technology Type	Rated Power in kW	Capacity in kWh	Status	Commissioning Date	Decommissioning Date	Service/Use Case 1	Service/Use Case 2	Service/Use Case 3	Service/Use Case 4
WPD Falcon Project, GE Durathon	Milton Keynes, Buckinghamshire	Electro-chemical	Sodium-nickel-chloride Battery	250	500	Decommissioned	01.11.2011	30.09.2014	Stationary Transmission/Distribution Upgrade Deferral	Voltage Support	Transmission Congestion Relief	Electric Supply Reserve Capacity - Non-Spinning
National Grid / RES	TBC	Electro-chemical	Lithium-ion Battery	20000		Contracted	31.12.2017		Frequency Regulation			
Batwind, Statoil	Peterhead, Scotland	Electro-chemical	Lithium-ion Battery	TBC	1,000	Announced	01.01.2018		Renewable Capacity Firming	Renewable Energy Time Shift		
Highview Viridor Pre-Commercial Demonstrator	Bury, Lancashire	Electro-Mechanical	Liquid Air Energy Storage	5,000	15,000	Commissioning	01.09.2016		Electric Supply Capacity	Electric Energy Time Shift	Frequency Regulation	Electric Supply Reserve Capacity - Spinning

Sources: REA Research and US Department of Energy Global Energy Storage Database, 2016 [last accessed 25/073/16]

Aggregated domestic installations

Project Name	Location	Technology Category	Technology Type	Aggregated Capacity in kWh	Aggregated Rated Power in kW	Status	Commissioning Date	AC/DC coupling	Service/Use Case 1	Service/Use Case 2	Service/Use Case 3	Service/Use Case 4
MOIXA – Maslow Distributed Storage (Utilities, solar homes, iUK, DECC)	Nationwide, e.g. Project Eric in Oxfordshire (innovateUK) 185KWh, Essex 170KWh (DECC)	Electro-chemical	Lithium Iron Phosphate battery (6k+ cycles)	1000 kWWh	200	Operational	2014 to 2016	AC	Domestic - self-consumption/ night storage shift	GridShare - VPP Grid Services - EFR/STOR/DTU	Gridshare - VPP DNO Services - Solar/night peak reduction, power quality	GridShare - VPP utility - Imbalance trading
Tesla Powerwall Installation	Cardiff, South Wales	Electro-chemical	Lithium-ion Battery	6.4 kWh	2	Operational	05.02.2016	DC	Domestic use and off-peak storage shift	Electric Bill Management with Renewables	Resiliency	
Aggregated anonymous small scale storage devices	Nationwide	Electro-chemical	Lithium-ion Battery	640 kWh		Operational	2015 to 2016	AC	Domestic use and off-peak storage shift	Electric Bill Management with Renewables	Resiliency	

This list only includes projects notified to the REA and was updated August 2016.

3.3. DNO Low carbon network fund projects

In the UK, Ofgem have funded a number of innovative projects aimed at the transition to a low carbon grid (the Low Carbon Network Fund). Many of these projects have included energy storage, as illustrated in the map below.

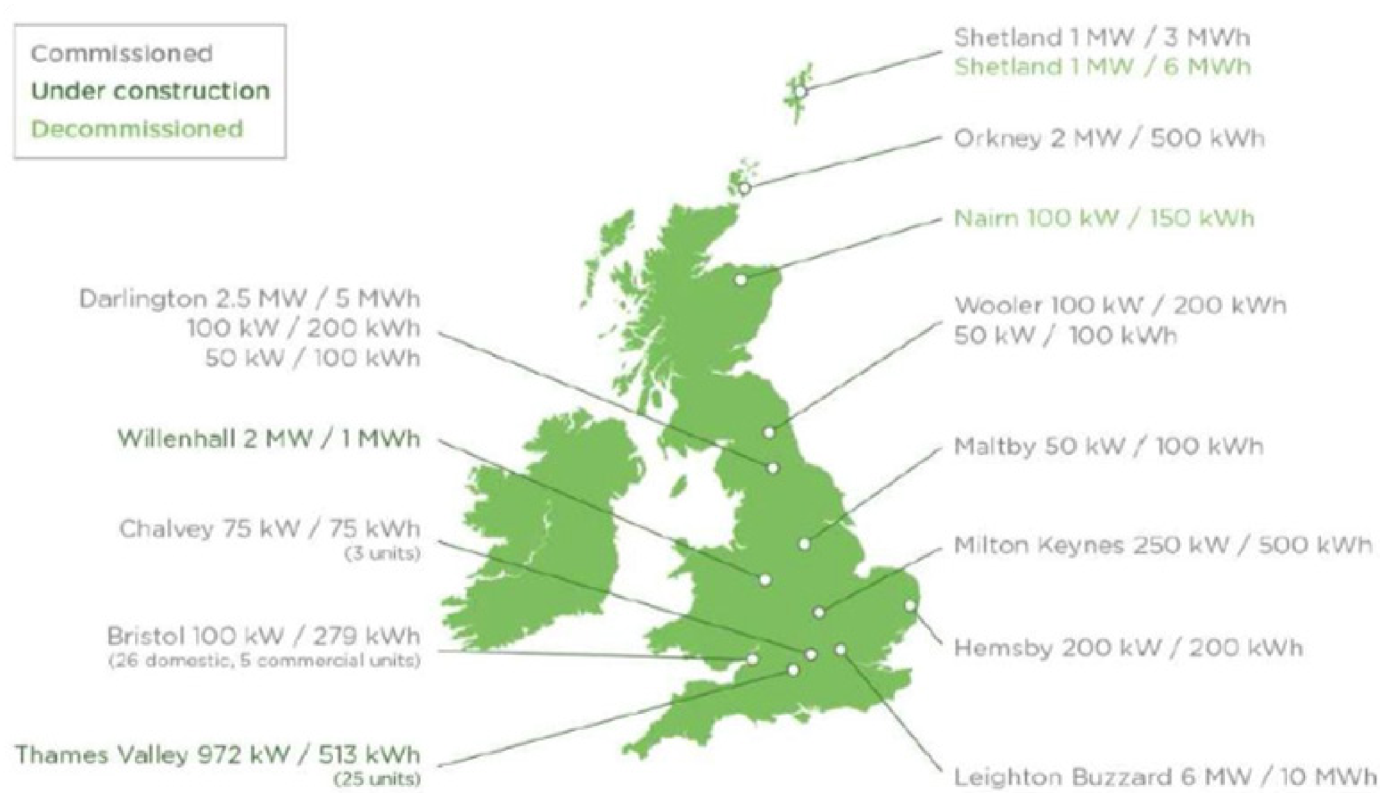

Figure 3-1 Energy storage projects funded by the LCNF programme (ESOF Group, 2014)

Section 4 - Industry Overview

Barriers and next steps for energy storage

Energy storage stands at something of a crossroads in the UK at the time of publication (autumn 2016).

Progress has undoubtedly been made, with the EFR auction results (200MW of frequency response capacity) providing impetus and leading the world in recognising this aspect of storage's potential. The biggest issue for larger scale storage projects however is the outcome of the Flexibility Call for Evidence jointly issued by BEIS and Ofgem, which could include a definition for storage and improvements to the grid codes as well as an emd to grid levy double charging for storage projects.

Meanwhile, behind the meter storage has the promise of half hourly domestic settlement on the horizon to encourage uptake, but details have not been forthcoming as to when this will arrive (although originally scheduled for 2017).

Strategic importance

The interviews current rate at which storage technologies are developing poses a strategic opportunity. In order to meet our environmental targets more storage technologies need to be deployed and in order to achieve this goal storage needs to be acknowledged as an essential part of the energy mix and appropriate support provided. The National Infrastructure Commission released their 'Smart Power' report in spring 2016 which outlined the case for storage as a strategic part of national infrastructure (NIC, 2016).

Improved perceptions: storage as a commercial proposition

Government has been forward looking in changing its perception of storage to some extent to acknowledge the commercial reality of being able to deploy on the ground at scale. If the UK does not want to fall behind (as happened with the wind industry) stakeholders must understand that storage is a rapidly maturing market. BEIS could support targeted projects that offer promise, and focus on the funding problems in the market.

Distribution network rules

Energy storage can bring benefits to transmission and distribution networks, greatly reducing the need to invest in reinforcements for the grid. Policy change to allow DNOs to install and operate ES systems as current licence conditions prevent this are hotly debated at present and a consensus is needed. There could be £2 billion worth of network savings by 2030 if appropriate levels of storage are installed (Strbac, 2012).

Securing financing

There have been a number of Government R&D funding mechanisms, for example Network Innovation Allowance and Low Carbon Networks Fund (LCNF) as well as other R&D funding sources. However, the 'valley of death' remains a major issue in the industry as firms face no financial support between the Government R&D funds and conventional debt finance entering the market. In the past year, several companies have secured finance via crowdfunding which highlights the lack of available mainstream finance and is a major barrier to the sector's growth. Arguably, because there isn't enough visible support or funding from the Government it makes it harder for investors to fund storage projects, which leads to a bottleneck in deployment. If there was more support from Government (other than R&D funding) it would stimulate more funding from private sector investors. This could be in the form of a high profile strategy or 'visible' commitment to storage, for example a target of 2GW deployed by 2020

Manufacturing and industrial opportunity

A number of energy storage technologies are being manufactured in the UK, indicating that there is large potential for energy storage technologies to benefit the UK economically in line with the Government's industrial strategy. However, if the UK does not take action to grow the market now then companies may have no other choice than to move production and deployment overseas. International competitors will be able develop faster than UK companies and eventually dominate the market at the cost to the UK of jobs and manufacturing opportunities.

A new definition and standards

Government, developers, installers, consumers, businesses, investors and UK storage companies all lack regulatory clarity on the sector. The lack of information limits the ability of the storage industry to grow. An agreed 'definition' is essential for ES to grow and this is being examined in the Government's Flexibility Call For Evidence. Industry consensus not just on the terms, but on how to implement them (via Licence Code or legislation for example), will be key.

Educating the market also continues to be essential to avoid 'cowboy' installers in the sector and because of the relative availability of battery parts and installation equipment for purchase online without guidance. The REA sees this as a priority and led the formation of an IET group to draft the first domestic and commercial battery installation guidance. The Technical Summary is now published and a full Code of Practice will be released in late 2016/early 2017. The REA and its sister body RECC worked with the BRE National Solar Centre to publish the first consumer guidance on purchasing battery storage units.

Section 5 - Conclusion

Industry has moved forward in the past 12 months and Government messaging has been positive, what is now needed is the awaited Call for Evidence outcomes on Flexibility (including energy storage) which will drive the market forward. One of the most encouraging messages is that the industry continues to strive to deliver without public subsidy. As the price of energy storage continues to fall, the case for storage becomes even more compelling, and the part storage can play in a sustainable decentralised energy future is clear (and highlighted in the REA/KPMG Report in 2016). The industrial strategy opportunities from storage should gain more traction in the newly merged BEIS department and this element must be highlighted to the BEIS.

Storage can be deployed at all scales, from large-scale pumped hydro, to domestic ‘behind the meter’ batteries. The roughly 800,000 solar PV installations in the UK, has been seen as a significant early market for ES, especially in conjunction with used electric vehicle batteries, both areas requiring regulatory change to take off. Based on typical daily household PV generation and electricity consumption profiles, storage can reduce household electricity bills and boost self-consumption of PV generation, also reducing system stress and carbon emissions. Installing large scale storage on the grid network better enables the balancing of supply and demand and assists in providing technical services such as frequency response and voltage optimisation, which the EFR tender has now made a reality. The REA also aims to highlight that energy storage options extend beyond batteries and electrical applications, as it can be applied across heat and transport, for example using hydrogen and thermal energy stores.

In summary the industry has identified a continued need for:

- High-profile Government support to provide investor confidence
- Improved access to finance
- Market education and information
- Developing the case for joint renewable energy / storage deployment
- An agreed ‘definition’ for energy storage
- The continued development of technical standards for installing and using energy storage technologies

The REA’s ‘UK Energy Storage’ group is dedicated to helping develop the market for energy storage in the UK and, enabled by its members, will continue to raise awareness and work to overcome the various barriers identified.

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Annex A

Table A-1 Detailed US storage policies as of Autumn 2016 (Table reproduced from US DOE website: **http://www.energystorageexchange.org/policies**, with added content)

Policy Name	Policy Description	Applies from - to
California Assembly Bill 2514	**California Public Utilities Commission** Bill 2514 was adopted to determine appropriate utility procurement targets. Since 2013 it has required California's three largest utilities to invest in over 1.3 GW of new energy storage capacity by 2020 with biannual targets increasing every two years from 2016-2020. Additionally, Electric Service Providers and Community Choice Aggregator were directed to procure energy storage resources equivalent to 1% of their peak capacity by 2020. Additionally, the bill permits companies other than large utilities to sell ancillary services in the electricity market.	01.01.2011 -
Con Edison Load Reduction Incentives	**Con Edison / New York State Energy Research and Development Authority** Con Edison filed a proposal to provide 100MW of load reduction measures including energy storage, energy efficiency and demand response as part of their plan for the potential shut down of the Indian Point nuclear reactor. In doing so, NYSERDA and Con Edison provided the public with information for their program. Accordingly, the new incentive offerings for systems that provide summer on-peak demand reduction are $2600/kW for thermal storage and $2100/kW for battery storage systems. Furthermore, they have also mentioned that, for larger projects with a minimum capacity of 500kW, there would be additional incentives, which will be capped at 50% of the overall cost.	01.05.2014 - 01.06.2016
Energy Storage Technology Advancement Partnership	**Department of Energy** The Energy Storage Technology Advancement Partnership (ESTAP) is a federal-state funding and information-sharing project, aimed at accelerating the commercialization and deployment of electrical energy storage technologies in the US.	
FERC Order 719	**Federal Energy Regulatory Commission** Under this order, FERC regulations under the Federal Power Act were amended and each independent system operator and regional transmission organization was required to either demonstrate that their tariffs were already in compliance with all of the areas mentioned below or to make filings that propose adjustments to their tariffs for compliance with all of the areas mentioned below; 1.Demand response and market pricing during periods of operating reserve shortage 2.Long-term power contracting 3.Market-monitoring policies 4.The responsiveness of independent system operators and regional transmission	12.16.2008 -
Long-Term Procurement Planning: Rulemaking 12-03-014	**California Public Utilities Commission** This rulemaking "authorizes Southern California Edison (SCE) to procure between 1,400 and 1,800 MW of electrical capacity in the West Los Angeles sub-area of the Los Angeles (LA) base and local reliability area to meet long-term local capacity requirements (LCRs) by 2021. SCE is also authorized to procure between 215 and 290 MW of the Moorpark sub-area of the Big Creek/Ventura local reliability area" (SCE, 2013).	13.02.2013 -

	This is the first state decision directing investor owned utilities to procure a certain amount of storage capacity (50 MW). It states that "energy storage resources should be considered along with preferred resources," (ibid) and that the two categories may be procured up to 800 MW of total capacity. "At least 50 MW [of capacity] must be procured from energy storage resources. At least 150 MW of capacity must be procured through preferred resources consistent with the Loading Order in the Energy Action Plan, or energy storage resources. SCE is also authorized to procure up to an additional 600 MW of capacity from preferred resources and/or energy storage resources" (ibid).	
Project Number 39917	**Public Utility Commission of Texas** With the ERCOT protocols, generators are compensated for energy on a nodal pricing model, meaning that the price of energy for a single location is subject to change depending on the grid traffic, whereas loads pay for energy on a zonal pricing model, meaning that the price of energy is the average of a number of nodes within a zone. As of now, there are eight zones in ERCOT. Even though energy storage facilities are treated as a load when it withdraws from the grid, the facility does not consume the energy but utilizes it for regeneration. Due to this reason, the Commission sought to couple the storage load at the nodal price. The difference between pricing mechanisms could have diminished the economic efficiencies when location and operation of storage technologies were considered.	12.11.2011 -
Smart Grid Demonstration Program	**Department of Energy** Smart Grid Demonstration Program (SGDP) projects are cooperative initiatives with the objective of demonstrating the advantages of the cost-efficient new technologies and analysing ways to integrating such tools and techniques on to those systems utilized today in order to improve them. The U.S. Department of Energy provides financial support of up to 50% of the SGDP projects' costs. Among the evaluated projects two were selected by the Department of Energy. The first one included regional smart grid demonstrations to observe grid viability and carry out cost benefit analysis. The second included energy storage technologies such as batteries, flywheels and compressed air energy storage systems for load shifting, ramping control, frequency regulation services, distributed applications, and the grid integration of renewable resources such as wind and solar power.	12.31.2007 -
Smart Grid Investment Grant Program	**Department of Energy** "The Smart Grid Investment Grant (SGIG) is a program with the purpose of hastening the modernization of the nation's electric transmission and distribution systems and promote investments in smart grid technologies in a multitude of areas including operational efficiency. The U.S. Department of Energy provides financial support of up to 50% of the SGIG projects' costs.	02.01.2010 -
Texas Senate Bill 943	**Texas Legislature** Under SB 943, which is concerned with the identification and classification of the utilization and regulation of electric energy storage facilities, active devices within the wholesale market must be registered as a Power Generation Company with the Public Utility Commission of Texas and must clarify that the energy storage is afforded all the same interconnection rights as other generation facilities, which are granted permission to interconnect, transmit and participate in the market. This particular bill does not identify the use of energy storage as a transmission asset.	09.01.2011 -

Self-Generation Incentive Programme	**California Public Utilities Commission** "The CPUC's Self-Generation Incentive Program (SGIP) provides incentives to support existing, new, and emerging distributed energy resources. The SGIP provides rebates for qualifying distributed energy systems installed on the customer's side of the utility meter" (CPUC, 2007). "Qualifying technologies include wind turbines, waste heat to power technologies, pressure reduction turbines, internal combustion engines, microturbines, gas turbines, fuel cells, and advanced energy storage systems" (ibid).	01.01.2010 - 01.01.2020

Annex B

Energy storage projects in the UK

Table B-1 Details of energy storage projects in the UK as of Autumn 2016

Project Name	Description
ABB & UK Power Networks Energy Storage Installation	DynaPeaQ is an energy storage installation for UK Power Networks in Norfolk, England. The system is a combination of ABB's SVC Light technology system for reactive power compensation and a Lithium-ion battery storage system and is used to feed energy to the local grid form the local wind turbines. The system enables absorbing and injecting power into the transmission and distribution system. The capacity of the distribution grid is 11kV and the storage system can store 200kWh of energy. For more information: http://www.abb.com/industries/ap/db0003db004333/8c1f3603e2c36bebc1257892003252aa.aspx?country=GB
AES Kilroot Station Battery Storage Array	On April 1st 2014, AES Kilroot Power Limited announced plans to build a battery store system of 100MW capacity in Northern Ireland. It will support the efficiency usage of wind power and improve grid efficiency. The storage system will be integrated into existing AES infrastructure at the Kilroot power station and could be online in the early second quarter of 2015. For more information: http://www.aesenergystorage.com/2014/06/08/aes-files-100-megawatt-grid-storage-connection-northern-ireland/
Cruachan Power Station	Cruachan Power Station is a pumped-storage hydro-electric power station which has been operational since 1965 and is one of four pumped storage power schemes in the UK. It can produce electricity for the grid in two minutes or if the turbines are already are in "spinning reverse" it can generate energy in only 30 seconds. The system is buried in the mountain and has four motor-generators which have a total output of 440MW of electricity. For more information: http://www.spenergywholesale.com/pages/cruachan_power_station.asp
Dinorwig Power Station	Buried deep below the Elidir mountain Dinorwig power station has six 300MW generating units, which use reversible pump/turbines that can reach maximum generation in less than 16 seconds and can provide power up to six hours. The system was designed to assist the National Grid in event of a complete power failure. For more information: http://www.fhc.co.uk/dinorwig.htm

EPSRC Grid Connected Energy Storage Research Demonstrator with Western Power Distribution (WPD) and Toshiba	Funded by the Engineering and Physical Sciences Research Council (EPSRC) aims to investigate the efficiency of energy storage connected to the electrical network and the supply of power and energy it feeds in to the grid at appropriate times. Supplied from the Toshiba Corporation a 2MW (1MWh) Lithium-Titanate battery based energy storage system would be installed in September 2014. Toshiba's SCiB system with 250kW of energy will further help investigate the use of repurposed second life EV batteries. Although, Western Power Distribution (WPD) is currently providing the point of network connection and a short term lease at their 11kV Willenhall substation, UK regulations prohibit distribution network operators from generating electricity or trading in energy markets. So while the project will be owned and operated by EPSRC, both partners will closely monitor the "effects on the network of this influx of energy storage, paying particular attention to the power requirement, diversity of connection and power quality experienced, to draw together a standard arrangement and assessment method for connecting more units in the future." For more information: https://www.epsrc.ac.uk/files/research/capital-for-great-technologies-call-grid-scale-energy-storage-panel/
Ffestiniog Pumped Hydro Power Plant	Ffestiniog Power Station was the UK's first major pumped-storage power station, which was commissioned in 1963 and currently has four power generating units with a combined output of 360MW - enough to power North Wales for several hours. For more information: http://www.fhc.co.uk/ffestiniog.htm
Flat Holm Microgrid Project	This project was installed in the summer of 2006 by Wind & Sun Ltd and includes battery/inverter systems, a 6kW wind turbine and two PV solar arrays. The batteries have storage capacity of over 27kWh to 50% depth of discharge. For more information: http://www.windandsun.co.uk/case-studies/islands-mini-grids/flat-holm-project,-bristol-channel.aspx#.VVsYVs6dJFI
Foula Community Electricity Scheme	The island is not connected to the mainland electricity grid and in 1987 a community electricity scheme was constructed which included diesel generators, a wind turbine and a hydroelectricity scheme all comprising 3.3.kV of grid electricity. However, this generation was problematic due to the islands location and issues with delivering fuel to the island during adverse weather conditions. Thus, the island's electricity grid was redesigned to have better renewable generation and decrease dependence on diesel fuel by the collaboration of Econnect Ventures and Wind & Sun. In Phase I completed in 2008) 19kW of PV cells, 140kWh battery packs to store energy harvested from the PV cells, replacing the existing Hydro-Generator and installing a new Hydro-Generator and laying a pipeline between the two sites. In Phase II (completed in 2011) the old Wind Turbine was removed, three new 10kW Westwind wind turbines were installed, a control centre for the turbines was built and battery packs were installed to store additional energy generated from the PV system. For more information: http://www.fces.org.uk

Foyers Pumped Storage Power Station	Foyers is a pumped-storage power station which also has a small amount of conventional hydro-electric capacity. The scheme was redeveloped in 1969 to focus more on pumped-storage and during the redevelopment the original power station was replace with a 5MW turbine in order to supply pure hydro-electricity. A new power station was built to house two 150MW Francis generation-motor sets which became operational in 1975. The turbines can reach full power from a standstill in less than two minutes which make them highly responsive to demand. The scheme is run by Scottish & Southern Energy and has a total capacity of 305MW. For more information: http://www.scottish-places.info/features/featurefirst3852.html
Gigha Wind Farm Battery Project	In order to store energy generated by wind, tide and wave power plants, the DECC project will install 1.26MWh vanadium redox flow batteries specifically to store power from the wind turbines. The installation is due in Q1 2015. For more information: http://www.communityenergyscotland.org.uk/gigha-battery-project.asp
Highview Pilot Plant	The (350kW/2.5MWh) pilot plant was connected to the grid and subjected to a full testing regime, including performance testing for the US PJM electricity market. In practical terms, the plant has operating hours equivalent to more than three years of UK Short Term Operating Reserve service (Highview Power Storage, 2015). For more information: http://www.highview-power.com
Horse Island Mi-crogrid Project	In 2009, a 2500Ah Rolls battery system and six 3kW wind turbines were installed to generate and store energy for the residents of Horse Island which also reduced their reliance on the diesel generators. For more information: http://www.windandsun.co.uk/case-studies/islands-mini-grids/horse-island.aspx#.VVskk86dJFI
Isentropic Demonstration Project	The project utilises pumped heat electricity storage which brings three essential features required from a storage technology; high efficiency, low capital cost and long life cycle. Each installation has a life cycle of 25 years with no limitation on the number of cycles or depth of discharge. The facility is capable of 1,900kW charging (input) power. For more information: http://www.isentropic.co.uk/Energy-Storage-Systems
Isle of Eigg Elec-trification Project	The island had a diversity of energy supply one 9.9kWp PV system, two 6kW and one 100kW hydro generation system and a 24kW wind farm which was supported by standby diesel generation and batteries. Econnect Ventures and Wind & Sun worked together to design battery inverters and PV systems, which make the Island's electricity system more sustainable in environmental and economic terms. The total energy storage of the system is approximately 212kWh to 50% depth of discharge (DOD). For more information: http://www.isleofeigg.net/eigg_electric.html

Orkney Storage Park Project	Scottish Hydro Electric Power Distribution (SHEPD) and Mitsubishi Heavy Industries Ltd have commissioned an energy storage system demonstration project using the distribution grid in the UK's Orkney Islands. The project aims at demonstrating power supply stabilisation in the region by introducing a container-housed large capacity energy storage system using lithium-ion rechargeable batteries, with a power output/ input capability of 2MW. The storage system was handed over for operation in 2013. The funding for the project is being provided to SHEPD from OFGEM, under the Low Carbon Network Fund. For more information: https://www.ofgem.gov.uk/sites/default/files/docs/2013/09/sset1007_close_down_report_final.pdf
Slough Zero-Carbon Homes Community Energy Storage	Three 25kWh lithium batteries were installed in the project, which aims to ensure that the power generated from PV panels can flow into the grid with, appropriate the technology. The batteries are connected at a strategic point, which will help spread demand and generation loads during the day. The focus of this project is to understand the benefits storage technologies can provide to low voltage networks. Additionally, the project is the first to be funded by Ofgem's Low Carbon Network Fund (LCNF) that places batteries close to customers' homes, instead of the point of use or at a substation. For more information: http://www.sandc.com/news/index.php/2013/01/sc-and-scottish-and-southern-energy-power-distribution-announce-pilot-storage-project/
Smarter Network Storage	This project aims tackle the challenges associated with low-carbon transition and increase economic deployment of storage by carrying out a wide range of technical and commercial innovations. Storage technologies are demonstrated across different part of the electricity system, which are also go beyond the boundaries of the distribution network. By demonstrating this multi-purpose application of 6MW/10MWh of energy storage at Leighton Buzzard primary substation, the project will explore the capabilities and value in alternative revenue streams for storage, whilst deferring traditional network reinforcement. An important aim of the project is to provide the industry with a detailed assessment of a storage projects' business case and full economic data consequently increasing intermittent energy sources integration to the grid and low carbon generation. The project was awarded funding from Ofgem's LCNF scheme of £13.2 million in December 2012 and will last until December 2016. For more information: https://www.ukpowernetworks.co.uk/internet/en/community/smarter-network-storage/
Willenhall Battery Storage Project	Combination of a 1MWh Toshiba lithium titanate battery combined with a 2MW ABB inverter to examine the effects of centralised energy storage on the grid, allowing experiments into response times for fast frequency response and other grid support functions. Sited on the primary 11kV grid at the Western Power Distribution electricity substation at Willenhall, Wolverhampton. There are bespoke dc-dc converters which can interface second life EV batteries to a 100kW ABB inverter to assess second life, or re purposed, EV battery packs in grid support applications. For more information: https://www.sheffield.ac.uk/creesa/willenhall

WPD Falcon Project, GE Durathon	The Falcon (Flexible Approaches to Low Carbon Optimised Networks) aims to reduce carbon emission levels within the electricity network and to investigate the benefits alternative to network reinforcement and how to increase efficiency. The project consists of five 50kW of Sodium Nickel Chloride Durathon batteries, which were supplied from GE and another smart technique. "The purpose of installation is to investigate using energy storage to defer costly network reinforcement and evaluate using a number of smaller batteries distributed across a network, rather than a single unit at a single location" (DOE, 2015). For more information: http://www.westernpower.co.uk/About-us/News/Falcon-flies-the-flag-for-innovation.aspx

Annex C

Enhanced Frequency Response (EFR) Tender Projects Awarded Contracts

Table C-1 Projects awarded Enhanced Frequency Response (EFR) Tender Contracts August 2016

Provider Name	Company SPV Name	Site Location Name	Enhanced Response (MW)	Estimated Start Date	Total Cost of tender £m	GWh of EFR holding	Service Hours
EDF Energy Renewables	EDF Energy (West Burton Power) Limited	T_WBURB-4	49	Dec-17	£ 12.035	1719.312	35088
Vattenfall	Vattenfall Wind Power Ltd	Pen Y Cymoedd	22	Apr-17	£ 5.749	771.936	35088
Low Carbon	Low Carbon Storage Investment Company Limited	Cleator	10	Dec-17	£ 2.681	337.6	33760
Low Carbon	Low Carbon Storage Investment Company Limited	Glassenbury	40	Mar-18	£ 12.668	1350.56	33764
E.ON UK	E.ON UK CHP Limited	Sheffield, S9 1HF/ Blackburn Meadows	10	Nov-17	£ 3.891	350.88	35088
Element Power	EPNED	TESS	25	Feb-18	£ 10.079	877.2	35088
RES	Battery Energy Storage Services 4 Limited	RESEFR7-PT	35	Feb-18	£ 14.651	1228.08	35088
Belectric	South East Grid Storage One Ltd	Nevendon	10	Oct-17	£ 4.200	350.88	35088

Source: National Grid Plc, 2016

About the REA

The REA was established in 2001, as a not-for-profit trade body, representing British renewable energy producers - the united voice of renewable energy and clean technology in the UK.

The REA endeavours to achieve the right regulatory framework for renewables to deliver an increasing contribution to the UK's electricity, heat and transport and green gas needs. It is influential in helping shape UK energy policy and has a track record in delivering high quality events on a wide range of energy related topics. REA aims to help its members build commercially and environmentally sustainable businesses.

REA Expertise

Renewable energy is a major component of low carbon energy policy for the future and is now a significant global business.

Energy storage technologies offer huge potential for the UK's energy supply. The industry can deliver significant benefits for both system stability and security of supply as well as helping decarbonise UK energy supplies. By delivering these new efficient, flexible energy systems, energy storage powerfully enables the deployment of renewables such as solar and wind.

UK Energy Storage by the REA is the trade body for storage technologies of every type and scale in the UK, whatever the application. The body exists to further the aims of energy storage companies and establish a clear marketplace and policy framework.

REA - #UKenergystorage
The home for UK energy storage

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