Energy Storage Research and Development

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Energy storage is principally aimed at coping with the fluctuations in demand for energy, for example meeting the peaks in demand on very cold winter days. Gas, oil and coal can be readily stored and these industries have well developed means for providing the appropriate storage facilities. Electricity by its nature cannot yet be readily stored in large quantities.

However, there is a widely held view that *electricity* storage has a role to play in the future of energy, helping to integrate increasing levels of renewable generation into the UK generation mix.

The main energy storage research and development (R&D) efforts in the UK are focussed on reducing the capital and running costs of the electricity storage technologies most suited to providing flexible local energy storage to electricity distribution networks.

These technologies include advanced battery systems, flywheels, compressed air systems and thermal-to-electric systems.

There is a wide range of sources of R&D funding from the UK central government, the Research Councils and the electricity companies through the Low Carbon Networks Fund that is funded as part of the current price control mechanism from consumer utility bills and regulated by Ofgem.

According to the Engineering and Physical Sciences Research Council, the UK is currently world leading in some niche areas of energy storage, such as lithium battery and super capacitor research, but may be less strong in others. Work is being focussed on those areas that would best benefit from new R&D efforts.

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2 Need for energy storage R&D

There is a widely held view that electricity storage has a role to play in the future of energy, helping to integrate increasing levels of renewable generation into the UK generation mix. [2]

The ability to store and release electricity at chosen periods provides flexibility and could help to mitigate the variability of renewable generation such as wind and solar. It would also have the advantage of enabling the capture of electricity when prices are low, or capturing electricity when supply exceeds demand. The ability to take electricity off the system when

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1 Engineering and Physical Sciences Research Council *review*

2 Institution of Mechanical Engineers *Energy Storage: The Missing Link In The UK's Energy Commitments*, April 2014

there is an oversupply of generation has the effect of flexing the generating capacity that is available.[3]

There are a number of challenges associated with electricity storage. Regardless of the type and scale of electricity storage, there will be specific fixed costs. In order to cover these fixed costs and make it a viable business, the storage device will require a certain number of cycles per year. For technologies where the fixed costs are high, as is often the case for technologies in their infancy, a high payment per cycle or a high number of cycles across the expected life of the asset will be required in order to recover the up-front costs. In addition, there is the challenge of 'round-trip' efficiency – the ratio of total electricity output (discharge) to the total energy input (charge); the lower the round trip efficiency, the greater the losses.

National Grid buys *Balancing Services* in order to balance electricity demand and supply. These services are currently provided through a number of routes, which electricity storage would have to compete against. Current balancing solutions include demand side response (DSR), interconnectors, flexible generation, and existing pumped hydro energy storage. [4]

In addition, there is likely to be increasing use of electric heat pumps, electric vehicles, and micro-generation placing further significant new demands on the UK's ageing electricity transmission and distribution networks.

Advanced storage technologies have the potential to meet these new stresses placed on the electricity system more cost-effectively than would be possible through traditional methods of grid reinforcement and fossil-fuel-powered system balancing capacity. Moreover, deployment of some key low carbon technologies is critically dependent on innovation in storage technologies. Most of these technologies are distributed storage options rather than bulk storage. Modelling work has suggested that distributed storage would be the preferred means for least cost electricity. [5]

Moreover, the new Capacity Market auction arrangements that are due to start by the end of 2014 have a specific provision for the trading of small scale as well as large scale electricity storage. [6]

The Minister of State (Michael Fallon) said

> DECC [..] regards storage along with demand side response (DSR)-as essential for a better functioning electricity market and both play an important role in ensuring security of supply.
>
> The Government is implementing measures to establish broader and more flexible DSR and Storage sectors as part of the Electricity Market Reform programme.
>
> Specifically, DECC will run two Capacity Market transitional auctions in 2015 and 2016, ahead of the Capacity Market's first full delivery year in 2018-19. These "transitional arrangements" will help grow the demand side and sub-50 MW storage industries and ensure effective competition between traditional power plants and new forms of capacity, driving down future costs for consumers.[7]

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3 POST *Electricity Storage* Number 306 April 2008
4 National Grid UK *Future Energy Scenarios*, July 2014 (particularly pages 115 to 121)
5 NERA and Imperial College London *Understanding the Balancing Challenge* 1 August 2012
6 DECC *Electricity Market Reform: Capacity Market – Detailed Design Proposals*, June 2013
7 HC Deb 08 Jul 2014 | 584 c204W

3 Energy storage technologies

The main focus of R&D into energy and particularly electricity storage is aimed at reducing the capital and operating costs of the various storage technologies that are likely to be available. The following technologies are the main focus of R&D spending:[8]

- *compressed air energy storage* (CAES) uses electricity to compress air and store it in an over- or underground reservoir; the electricity is produced when the compressed air is expanded and directed through a turbine;
- *sodium-based batteries* utilize molten sodium, sulphur and ceramic separator as anode, cathode and conductive electrolyte respectively;
- *redox flow batteries* are electrochemical devices that can accumulate (charging mode) and deliver (discharging mode) energy via reversible reduction-oxidation reactions of electrolytes either in liquid or gaseous form that are stored in separated storage tanks;
- *lithium-based batteries* are known for their good power and energy densities, and to have reasonable cycle life provided they are not operated over a wide state of charge range;
- *flywheels* can be viewed as kinetic or mechanical batteries; flywheel energy storage works by boosting a rotor (flywheel) to a very high speed and keeping the energy in mechanical/rotational form;
- *super-capacitors* store energy in the form of separated charges at porous electrodes divided by electrolytic solution; due to their high power density but relatively low energy density, super-capacitors are well suited to voltage and frequency stabilisation;
- *thermal-to-electric storage* uses two large containers of mineral particulate (gravel for example); electricity is used to pump heat from one vessel to the other, resulting in the first container cooling to around -160 °C and the second container warming to around 500 °C; and
- *fuel cells* generate electricity from hydrogen and oxygen/air while the electrolysers produce hydrogen and oxygen from water and electricity; individual fuel cell and electrolyser units can be assembled into bigger modules to generate more electricity and hydrogen; in order to store the energy there is a need to have hydrogen storage, for example as compressed gas.

Most of these technologies already exist or are at the early stage of development. A report by the Carbon Trust sets out further details. [9]

Energy storage is closely linked with other technology areas

- for use as a potential source of demand response,

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[8] Low Carbon Innovation Coordination Group *Technology Innovation Needs Assessment (TINA) Electricity Networks & Storage*, August 2012

[9] Carbon Trust *Strategic Assessment of the Role and Value of Energy Storage Systems in the UK Low Carbon Energy Future* June 2012 (pages 89-95)

- as a key integrated component of electric vehicles,
- use with more advanced control systems for effective dispatching.

4 R&D projects

Energy storage R&D in the UK is conducted through a number of bodies.

The *Engineering and Physical Sciences Research Council (EPSRC)* has invested £30 million in five centres to support new science capital facilities for grid-scale energy storage to help accelerate the development of national scale electricity storage.

In addition, the SUPERGEN Energy Storage Hub draws experts together from seven universities and fourteen industrial and governmental partners. They will address the technical and scientific challenges facing the wide variety of energy storage techniques.

Most recently a £4 million fund for collaboration between academics and industry is being set up for the direction and development of research and technologies in Energy Storage was announced on 4 May 2014. This will be managed by the EPSRC, on behalf of the Research Councils UK Energy Programme (RCUK).

The *Energy Technologies Institute (ETI)* has funded a number of projects and companies through its Energy Storage and Distribution Programme, including project of £14million investment to build a 1.5MW storage system at a Western Power Distribution substation

Ofgem established the Low Carbon Networks (LCN) Fund as part of the electricity distribution price control that runs until 31 March 2015. In the two years since its inception, the LCNF has committed over £100 million to a range of projects that demonstrate storage, electric vehicle charging, demand response, distributed generation, and advanced monitoring and control technologies.

The *Technology Strategy Board (TSB)* recently accepted proposals for its new Smart Power Distribution and Demand programme, which will provide £2.4 million for feasibility studies related to automated power distribution and demand management. TSB has also led the Smart Grid Special Interest Group (SESIG) to map and coordinate research in this area.

The *Department of Energy and Climate Change's (DECC)* innovation support programme for all energy R&D totals £200 million for the period 2011/12 to 2014/15, for energy storage it includes

- £3 million for Component Research and Feasibility Study Scheme (redox batteries, fuel cells, hydrogen safety, small scale batteries and novel pumped storage)
- £17 million for Technology Demonstration Competition (compressed air storage, thermal storage, redox batteries, back up resilient power for local wind and solar sources, flywheel)
- £3 million for heat storage
- £10 million for Energy Entrepreneurs Fund (fuel cells, heat storage, super capacitors, flywheels, batteries)

The *European Union* has funded a survey of energy storage projects and investments.

5 R&D funding

In 2011/12, UK total spend on public sector energy research, development and demonstration was £358 million. DECC has a £150 million programme of innovation support from 2011 to 2015 for key low carbon technologies, including: electricity storage; energy efficiency in buildings; marine; bioenergy; and offshore wind.

This spending complements a wider package of support offered by the members of the Low Carbon Innovation Coordination Group worth more than £1 billion from 2011 to 2015 that also includes support for energy storage. [10]

Submissions to the International Energy Agency on specific funding for energy storage and fuel cell R&D and demonstration projects is summarised below.

Government energy storage and fuel cell funding (£ million)

	Energy storage		Fuel cells	
DECC	2012/13	2013/14	2012/13	2013/14
R&D	0.10	1.06	0.11	0.92
Demonstration	0.02	4.22		
Total Government				
R&D	5.42	8.99	13.24	13.21
Demonstration	0.64	4.89	0.34	0.31

Source: International Energy Agency

6 Evaluation of electricity storage R&D efforts

According to the Engineering and Physical Sciences Research Council (EPSRC), the UK is currently "world leading in some niche areas of energy storage such as lithium battery and super capacitor research but less strong in others" according to advice received from the *International Review of Energy 2010*, the Energy Research Partnership and the RCUK Energy Programme Scientific Advisory Committee. However, according to the EPSRC, the energy storage community is also dispersed and focused around specific technologies and links between energy storage and the greater energy system need strengthening.

7 New transport technologies

Expansion of the electric vehicle fleet and the accompanying re-charging network is seen by many as a further means for storing electricity and performing a similar role to the electricity storage technologies outlined above.

In answer to a written PQ, the Minister of State (Charles Hendry) said

> DECC's Carbon Plan assessed that 20% to 50% of new cars and vans could be battery electric, range extended electric or plug-in hybrid in the UK by 2030. Since they can be charged at any time of the day, plug-in vehicles could help introduce flexibility to the electricity system, allowing electricity demand to be shifted to better match electricity supply and to make more efficient use of network infrastructure.[11]

[10] DECC *Annual Energy Statement 2013* Cmnd 8732 October 2013

[11] HC Deb13 Mar 2012 | 542 c159W

The Government has made substantial provision for the promotion of low carbon vehicles. In response to a written PQ, the Minister of State (Michael Fallon) said

> The Government has made provision of over £400 million for measures to promote the uptake of ultra-low carbon vehicles in the UK. This includes approximately £80 million supporting research and development activities; £30 million for the installation of infrastructure; and £300 million to support consumer incentives for the life of the Parliament.
>
> BIS, with the Technology Strategy Board (TSB) and the Office for Low Emission Vehicles has to date invested over £150 million in more than 100 major automotive research, development and validation projects under the TSB's Low Carbon Innovation Platform which has been more than matched with around £200 million of private sector funding. In addition, TSB recently announced £7.5 million funding for five major research and development projects which could speed-up the adoption of energy systems using hydrogen and fuel cell technologies.
>
> At the Low Carbon Vehicle 2012 event on 5 September 2012, I announced £9 million of new funding to support the creation of an Energy Storage Centre based at the High Value Manufacturing Catapult.
>
> Further competitions under the Low Carbon Vehicles Innovation Platform are under consideration which would likely be formulated around strategic CO_2 reduction technologies identified by the Automotive Council.[12]

[12] HC Deb15 Oct 2012 | 551 cc252-4W