sandbag

Energy storage & battery technology

Response to the National Infrastructure Commission call for evidence

March **2017**

The UK electricity market is changing fast. By 2030, most of the UK's electricity will come from nuclear, wind and solar. To utilise this low-carbon and near-free power requires a new grid infrastructure, with batteries and energy storage technology as an essential component.

About Sandbag

Sandbag is a London and Brussels-based not-for-profit think tank conducting research and campaigning for cost-effective climate policies.

Our research focus includes reform of the EU Emissions Trading System and the Effort Sharing Regulation; accelerating the phase-out of old coal in Europe; deep decarbonisation of industry through technologies including Carbon Capture & Storage; and improving national and international climate governance.

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With the extremely successful coal phase-out already well underway, prices for solar photovoltaics and wind (both onshore and offshore) are falling beyond all analysts' expectations, meaning coal generation will be replaced renewables generation. Changing power sources and consumption habits requires new infrastructure to ensure the resilience of this new grid, and to maintain productivity. Energy storage of many kinds will be essential for infrastructure productivity and therefore fits the call for evidence by the National Infrastructure Commission.[1]

This briefing focuses on lithium-ion batteries, which are immediately available at scale, but other energy storage options are increasingly available, which offer longer duration power, and allow more of the jobs and industrial value-chain to sit in the UK, including:

- Hydrogen fuel cells
- Flow batteries
- Air storage
- Pumped hydro

All infrastructure development over the next 10-30-year time horizon must be compatible with the UK Climate Change Act which legally binds the government to reduce emissions by at least 80% from 1990 to 2050.

The following headings will briefly answer the Commission's specific questions, alongside references to further work that explains the importance of energy storage technology to British industry and infrastructure.

[1] *National Infrastructure Commission call for evidence: Technology* https://www.gov.uk/government/news/nic-launch-technology-study-call-for-evidence

Sandbag's vision for 2023: The remaining 6GW of coal plant in the Capacity Auction is replaced with electricity storage, a significant portion of which is built from a thriving UK-based energy storage industry

The 2016 Capacity Market auctions contracted 500MW of new battery capacity, which was very welcome for the transition to a resilient and low-carbon grid.[2] However, in the National Grid's lowest-carbon and lowest-cost scenario, 18.3GW of battery storage will be connected by 2040.[3] To achieve this fundamental infrastructure change, a new focus needs to be placed on building a UK battery industry. 6GW of coal capacity remains to be replaced in the coming Capacity Market Auctions; Sandbag believes the coal phase-out, and an associated increase in energy storage capacity, can be completed by 2023.[4]

Generation capacity can be replaced with energy storage, because storage allows excess electricity generation (from renewables) to be used at a time when demand peaks.

Advances in battery technology are now internationally important, with batteries and other energy storage essential as more renewable energy is added to national and regional grids, and lithium-ion batteries specifically essential for the Electric Vehicle revolution. With the IEA Two Degrees Scenario predicting 13 million electric cars on the road by 2020, and 140 million by 2030,[5] this is a very significant new industry for the UK to be part of.

How does the technology improve British infrastructure productivity?

Energy storage technologies increase the productivity of electricity generation and improve security of supply by reducing wastage at times of renewable or nuclear oversupply, and in allowing the grid to become more responsive to changes in demand for electricity.

Additionally, energy storage technology is just on the cusp of global ubiquity. Tesla's first Gigafactory in Nevada will employ 10,000 people when fully operational, and Tesla will shortly be expanding to Europe, with other companies beginning construction across the EV and energy storage sector. The UK could harness this new industry and the jobs it guarantees.

Energy storage is part of the new smart electricity grid which offers the lowest-cost route to decarbonisation of UK electricity, avoiding the expensive construction of a fleet of Combined Cycle Gas Turbine plants which must then be closed and replaced around 2030 as the carbon budgets tighten. By 2030 the UK power system must average 50-100g/kWh, which requires at most ~100TWh of unabated gas.[6] UK gas plants produced 146TWh in 2016.[7] By 2050 the UK's electricity mix must have net zero emissions and, as such, infrastructure investments made now must align with this trajectory.

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[2] *UK Capacity Market analysis (December 2016) Sandbag https://sandbag.org.uk/project/uk-capacity-market-analysis-2/*
[3] *Future Energy Scenarios (2016) National Grid http://fes.nationalgrid.com/fes-document/*
[4] *Consultation response: Phasing-out coal by 2023 (Feb 2017) Sandbag https://sandbag.org.uk/project/phasing-coal-2023/*
[5] *World Energy Outlook (2016) IEA http://www.iea.org/publications/freepublications/publication/global-ev-outlook-2016.html*
[6] *Power sector scenarios for the fifth carbon budget – Page 93 (Oct 2015) The Committee on Climate Change https://www.theccc.org.uk/wp-content/uploads/2015/10/Power-sector-scenarios-for-the-fifth-carbon-budget.pdf*
[7] *The Energy Transition in the Power Sector in Europe. (Jan 2017) Sandbag and Agora Energiewende https://sandbag.org.uk/project/energy-transition-2016/*

What stage has the technology reached in terms of demonstration and uptake?

In the last T-4 UK Capacity Market Auctions, 501MW of utility-scale battery secured 15 year contracts.[8] UK Power Networks has received 667 connection applications totalling 12.2GW for energy storage (almost all batteries) over the last 15 months from January 2017.[9]

In the USA, the first Tesla Powerwall power plant is now operational. At Mira Loma, California, an 80MWh plant went from contract to commissioning in under 3 months, providing four hours of power as an alternative to expensive and dirty gas peaker plants.[10] Rapid progress in the technology has seen a five hour 52MWh plant completed in Hawaii,[11] and a 100MWh-300MWh plant proposed in South Australia,[12] with prices at approximately $50 million (£40 million) for a 100MWh plant.

States in the USA including California and Massachusetts are now mandating energy storage. California has regulated utilities to install at least 1.3 gigawatts of storage by 2020.[13] If the UK acts now it can build a major lithium-ion battery industry in the next few years, and take advantage of the global market, with a predicted battery capacity of 150-240GW by 2030.[14]

Other energy storage methods

Flow batteries:[15] Mainly vanadium, these batteries are at a less advanced stage of development, but offer a high rate discharge over periods of up to 10 hours, and so might allow for longer lasting backup. Microsoft is testing commercial flow batteries, configurable in capacities up to 25MW, at a data centre in Washington.[16]

Hydrogen fuel cells: These show promise for long-term power, but require a fuel source. Major projects include a 3.7MW project in Connecticut, USA.[17] Their potential is vast, and like the lithium battery, several large automotive companies are investing huge amounts in research and already are ramping up production.

Air storage: Undersea air storage is similar to pumped hydro power, but does not require the favourable geography of Norway to operate. In the UK, Highview Power uses liquid air for energy storage, promising from 5MW/15MWh – to more than 200MW/1.2GWh.[18] Hydrostor is one Canadian company testing a 1.75MW undersea balloon power

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[8] *UK Capacity Market analysis (Dec 2016) Sandbag https://sandbag.org.uk/project/uk-capacity-market-analysis-2/*

[9] *Energy Storage Boom (Jan 2017) UK Power Networks http://theenergyst.com/energy-storage-boom-uk-power-networks-receives-12gw-of-connection-applications/*

[10] *Mira Loma Substation (January 2017) Inside Edison http://insideedison.com/stories/innovative-battery-storage-facility-at-sces-mira-loma-substation-allows-for-more-renewables*

[11] *Innovative Renewable Peaker Plant (January 2017) Kaua'i Island Utility Cooperative http://kiuc.coopwebbuilder2.com/sites/kiuc/files/PDF/pr/pr2017-0110-AES%20Solar.pdf*

[12] *We can solve SA's power woes in 100 days (March 2017) Australian Financial Review http://www.afr.com/news/tesla-battery-boss-we-can-solve-sas-power-woes-in-100-days-20170308-gut8xh*

[13] *California to add 1.3GW by 2020 (2013) Bloomberg https://www.bloomberg.com/news/articles/2013-10-17/california-agrees-to-add-1-3-gigawatts-of-power-storage-by-2020*

[14] *IRENA, Renewables and Electricity Storage (June 2015) http://www.irena.org/DocumentDownloads/Publications/IRENA_REmap_Electricity_Storage_2015.pdf*

[15] ***Lead-acid batteries** are the most widely used on the grid until recently, but despite their low-cost have lengthy charge times, low-energy density and require maintenance, making them less suitable for grid-balancing than lithium-ion batteries. There are over 100MW of lead-acid batteries connected to the UK grid. Lead-acid batteries have benefits for smoothing solar PV electricity production; in 2009, for example, China was installing lead-acid batteries in 75% of new solar photovoltaic plants. http://www.iea.org/publications/freepublications/publication/global-ev-outlook-2016.html*

[16] *Primus flow battery (March 2017) Utility Dive http://www.utilitydive.com/news/primus-power-begins-production-of-5-hour-flow-battery/436998/*

[17] *FuelCell Energy Announces Approval by the Connecticut Green Bank of Financing for a 3.7 Megawatt High Efficiency Utility-Scale Project (March 2017) Nasdaq http://www.nasdaq.com/press-release/fuelcell-energy-announces-approval-by-the-connecticut-green-bank-of-financing-for-a-37-megawatt-20170314-00527*

[18] *Highview Power http://www.highview-power.com/*

plant, using compressed air to generate electricity,[19] whilst pilot testing is now complete on the German StEnSea underwater concrete globes, which at full size will provide up to 30MWh per 30m globe.[20]

Goodenough glass batteries: These Google-backed sodium-ion batteries promise an energy density three times greater than today's lithium-ion batteries, for a much lower cost.[21] There are no current commercial projects.

What evidence is there supporting the likely costs of introduction?

Battery prices are decreasing at unprecedented levels, outpacing all analyst's predictions,[22] with falling cost of 70% through the 18 months to June 2016.[23] In 2010, each kWh would cost $1,200; EV batteries are now below $200 a kWh, and Tesla claims it will be producing batteries below $100/kWh (£80/kWh) by 2020.

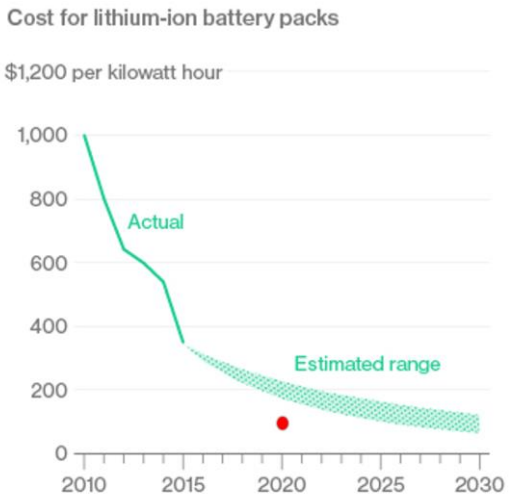

Figure 1 Battery price costs and predictions from Bloomberg New Energy Finance (2016 prices and Tesla's 2020 price expectation is already below the estimated range)[24]

Hawaii's solar and lithium-ion battery plant cost the utility $0.139/kWh over a 20 year contract, lower than the utility's $0.1548 cent cost for diesel plants, and half the consumer's $0.2768 cent cost of electricity (£0.23).[25] The standard rate for consumer electricity in the UK is currently £0.1386/kWh.[26]

Energy storage providers can also take advantage of the huge differences in peak and off-peak electricity prices which can differ by up to 300%.[27]

[19] *Pumped storage gets a makeover (Nov 2016) The Economist* http://www.economist.com/news/science-and-technology/21709527-pumped-storage-gets-makeover-depths-imagination

[20] *Fraunhofer Tests a New Underwater Energy Storage Concept (August 2016) GTM* https://www.greentechmedia.com/articles/read/fraunhofer-races-hydrostor-for-underwater-storage

[21] *Google's Schmidt Flags Promise in New Goodenough Battery (March 2017) BNEF* https://about.bnef.com/blog/google-ceo-schmidt-flags-promise-of-new-goodenough-battery/

[22] *The age of the giant battery is almost upon us (Feb 2017) Bloomberg New Energy Finance* https://www.bloomberg.com/news/articles/2017-02-21/big-batteries-coming-of-age-prompt-bankers-to-place-their-bets

[23] *Battery prices fall 70% (June 2016) GTM* https://www.greentechmedia.com/articles/read/stem-cto-weve-seen-battery-prices-fall-70-in-the-last-18-months

[24] *Pencils down for Tesla Model 3 (July 2016)* https://www.bloomberg.com/news/articles/2016-07-27/elon-musk-says-it-s-pencils-down-for-tesla-s-model-3

[25] *Tesla Completes Hawaii Storage Project That Sells Solar at Night (March 2017) Bloomberg* https://www.bloomberg.com/news/articles/2017-03-08/tesla-completes-hawaii-storage-project-that-sells-solar-at-night

[26] *Energy Saving Trust (March 2017)* http://www.energysavingtrust.org.uk/about-us/our-calculations

[27] *Drax Electric Insights. Online dashboard tool* http://16058-drax-staging.s3-website-eu-west-1.amazonaws.com/#/dashboard?start=2017-03-06&&_k=q76gbv

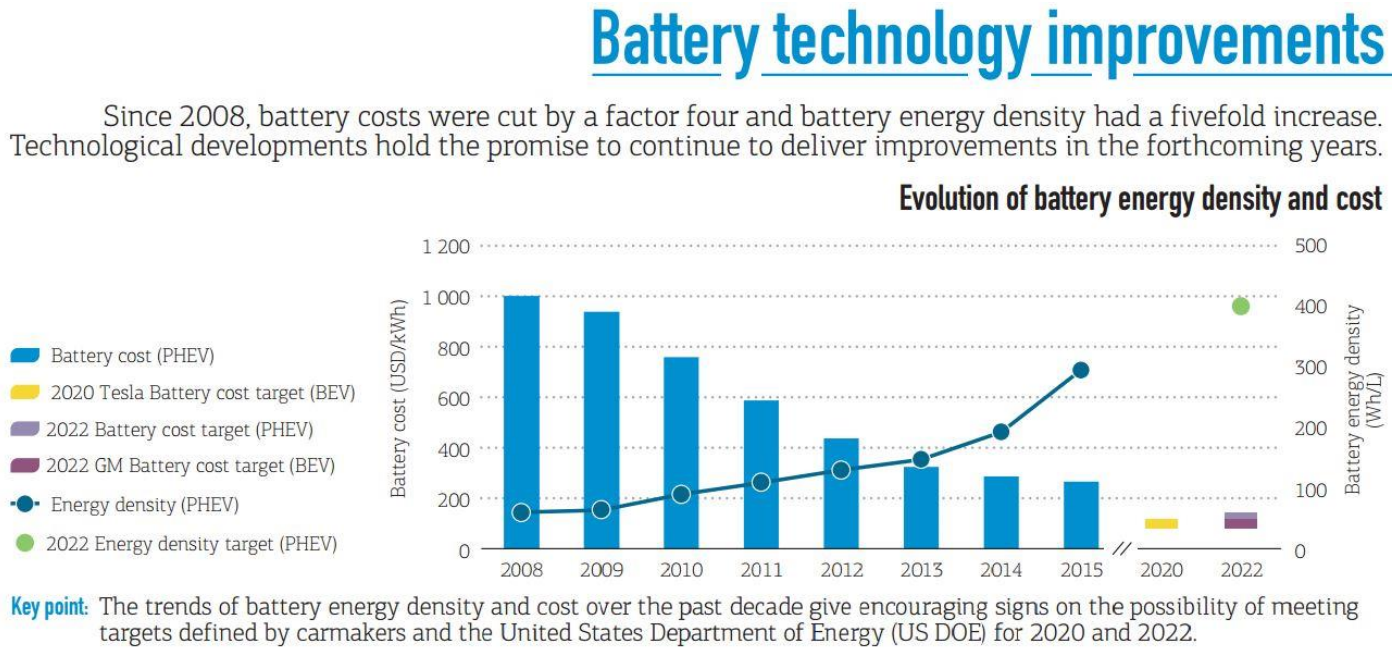

Figure 2 Graph from International Energy Agency (IEA) World EV Outlook 2016[28]

What are the principal challenges and barriers which need to be addressed to enable the maximum uptake of the technology?

Energy storage research is now essential to continue the technology's astonishing recent gains, and government support for commercialisation research would be a major aid to this new infrastructure.

Future auctions on the UK Capacity Market, alongside the Enhanced Frequency Reserve, need to better recognise and support the benefits of flexibility offered by energy storage, to ensure a greater proportion of new capacity contracted is battery and other storage.

Efficiently using new energy storage infrastructure requires a parallel expansion in demand side response and smart, fully-digitised grids.

Would the introduction of the technology imply major changes to existing infrastructure, require new infrastructure, or does it fit with existing infrastructure?

As the grid is upgraded to integrate more closely with power from Europe, including an expansion in interconnectors, and to cope with the transition towards small distributed generation and renewables, major infrastructure changes are occurring. As we build more wind and close coal, the idea that we would also need to build a fleet of new gas infrastructure is out-dated. Electricity storage provides a much more attractive proposition for creating jobs and linking in the renewables growth happening now in the UK. The rapid price falls of storage technology should allow the UK to leapfrog the 'gas bridge' and move directly and cost-effectively to a modern, ultra-low-carbon power sector.

Contact phil@sandbag.org.uk or on (+44) 020 3876 6451 for more information

[28] *International Energy Agency (IEA) World EV Outlook 2016*
http://www.iea.org/publications/freepublications/publication/global-ev-outlook-2016.html