

Energy: Issues & Concerns: (M7X01805)



Abstract

This report focuses on the problem of intermittency in renewable sources and how energy can be stored efficiently. It will also examine the impact of energy storage technologies and identify the key UK actors, effectiveness and timescales for implementation.

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Energy: Issues & Concerns: (M7X01805)

There has been increased uptake of renewable energy, stimulated in part from targets set both domestically and internationally. There is, however, an issue with intermittency of supply from certain renewable sources.

You are to investigate what steps or technologies could be applied to solve the issue of intermittency from renewable supply. If looking at steps, you should define the key actor(s) involved and the effectiveness of the steps in the short, medium and long term. If looking at technologies, some issues to consider include lifespan, integration, applicability and scale, as well as market readiness.

You are to present this in a professional style report, 3000 words +/- 10%.

This report focuses on the problem of intermittency in renewable sources and how energy can be stored efficiently. It will also examine the impact of energy storage technologies and identify the key UK actors, effectiveness and timescales for implementation.

Intermittency is defined as the periods when a renewable source is completely cut off to due atmospheric and environmental conditions. For example, during a storm too much wind can damage generators consequently the generators are shut down and no energy is produced.

Energy Storage (ES) is a form of storing energy from a renewable source during times when supply is greater than demand and releasing the energy back for consumption during peak periods of demand. Methods of storing energy include using turbines such as Pumped Hydro Storage (PHS), Flywheels, and various battery storage technologies.

The UK's Department for Business Innovation and Skills has identified ES as one of "Eight technologies the UK could be world leaders in." (**Gov.uk, 2014**) But in order for the UK to reach this, investment must happen in order to develop ES.

In 2006 Demirbas estimated that 14% of the world's energy supply came from renewable sources (**Demirbas, 2006**). Renewable energy is generated by multiple sources and technologies including solar, wind, pumped hydropower, geothermal and tidal energies amongst others.

Hardisty argues "Most forms of renewable energy are unreliable i.e. the wind does not blow all of the time, and this is taken into account when analysing the financial viability of a project" (**Hardisty, 2008:76**). Despite these perceived problems electricity generation from wind and solar energy, hydropower is more reliable and is more efficient at producing electricity (**U.S Office of Energy Efficiency**).

Another difficulty with renewable sources is that they do not necessarily generate enough electricity to match demand during peak energy consumption.

There has been an increased uptake in renewable energy technologies in the United Kingdom (UK) guided by policies such as the Climate Change Act (2008) and The Low Carbon Plan (2012). On the contrary renewable energy uptake worldwide has progressed slowly despite binding international agreements such as The Kyoto Protocol (1997) and The Paris Agreement (2015).

Thesis

In order to address the issues of intermittency in some renewable sources there is a body of thought that suggests integration of a SMART grid which is a “self-managing and reliable transmission grid that would use Information Communication Technologies (ICT) to conduct an automated system of monitoring, control and protection” (**cited in Blarke and Jenkins, 2013**) would help solve the problem of intermittency. Another solution might be the integration of a SuperGrid which is an adaption of the current grid network that facilitates large quantities of renewable energy into the energy mix.

This report intends to promote ES as a viable solution to mitigate against intermittency. It will examine the generation, supply and transmission of renewable energy sources into the grid together with the integration of these new technologies into a SMART grid system which would allow UK citizens and businesses to meet their current and future energy needs.

Roadmap

This report shall examine how ES is being implemented in the UK to solve intermittency in renewables. It composes of three sections:

Section 1: ES Technologies

This will examine the lifespans of various ES technologies and how ES technologies are integrated within the UK. The applicability and scale of each technology will be analysed and suggestions made how these technologies can be developed further. An evaluation will be undertaken to assess market readiness of each technology and to summarise the potential benefits and shortcomings.

Section 2: Steps

This will identify the key actor's involved in implementing ES in the U.K. from the U.K. Government and regulation bodies, electricity providers, the scientific research community and The National Grid. This section shall also examine the effectiveness of actions already introduced in the short, medium, and long term.

Section 3: A case study of ES in Jamestown, South Australia

This will discuss a case study where ES has been recently implemented outside the U.K., evaluate whether the U.K. can easily integrate this technology.

Finally, some concluding summaries and recommendations on the findings of this report.

Section 1: ES Technologies

1.1 Mechanical ES

Mechanical ES comprises of any system of ES that is mechanically driven.

This section analyses:

- Pumped Hydro Storage (PHS)
- Flywheels
- Compressed Air Storage Systems (CAES)

Pumped Hydro Storage is when water is transported from a low laying reservoir to a higher-level reservoir through pipes driven by pumps and turbines (**Foley et al, 2015**). PHS can be combined with Wind Energy in order to mitigate against intermittency.

Figure 1. PHS storage plant diagram



Source: Renewable Energy Association (2016), *Energy Storage in the UK, an overview*

PHS is a mature technology that has been used for decades. The technology is expensive to install and relies on specific topography (**REA, 2016**). Due to these installation and location issues it would be difficult to integrate this technology on a large scale in the UK. This technology is already available on the market but due to these specific optimal conditions is not widely applicable.

Flywheels are “an electromechanical system that stores energy in form of kinetic energy. A mass rotates on two magnetic bearings in order to decrease friction at high speed, coupled with an electric machine. The entire structure is placed in a vacuum to reduce wind shear” (**Diaz-Gonzales et al, 2012:2160**).

Flywheels have a long lifespan and are low maintenance. Once installed they are constructed with environmentally inert materials and have a high efficiency in terms of energy conversion (**Diaz-Gonzales et al, 2012**). This technology is available to buy commercially however the technology is newly developed. Flywheels are currently used in vehicles engines and power plants (**IEC, 2011**). Flywheels have been recorded to lose up to 20% of their storage capacity per hour therefore making them ineffective for long term energy storage (**Hadjipaschalis et al, 2009**).

Compressed Air Storage Systems (CAES) can store energy either underground or at ground level in an air tank. The air is compressed through an electrified motor that serves to push the air through a turbine. Integration of this technology is dependent on geology especially with underground installations. This technology can be utilised with Wind Energy, Solar Energy and existing grid infrastructure to mitigate against intermittency. CAES can produce three times the amount of energy of a conventional gas turbine of similar size making this system an effective way of ES (**NECEC.Org, 2007**).

Table 1: Summary of mechanical ES technologies

Mechanical ES category	Lifespan	Integration	Applicability and scale	Market ready
PHS	Long lifespan	Not easily integrated	Requires specific optimal conditions so not widely available	Yes
Flywheels	Long lifespan	Widely integrated	Widely available	Yes
CAES	Long lifespan	Not easily integrated	Requires specific geological conditions	Yes

1.2 Battery ES

Conventional battery technology has been in use since the late 19th century. Battery ES is the process of converting energy from mainly electrical sources into storage cells, this process can also be reversed (**Luo et al, 2015**). Battery ES can be separated into three categories:

- Conventional batteries e.g. Lead Acid, Nickel-Cadmium (NiCd) and Lithium Ion
- High temperature batteries e.g. Sodium Sulphur (NAS), Sodium Nickel Chloride (NaNiCl) and Copper/Zinc Rechargeable batteries
- Flow batteries e.g. Radox Flow Battery

The following table summarises the lifespan, integration, applicability and scale and market readiness of each category of battery ES.

Table 2: Summary of battery ES technologies

ES battery category	Lifespan	Integration	Applicability and scale	Market ready
Conventional batteries	Variable life cycles. Lead Acid batteries have a short lifespan whilst Nickel- Cadmium have longer lifespan	Lead Acid and Nickel- Cadmium are used commercially. Although NiCd is potentially explosive and only used in stationary for safety reasons (REA, 2016)	There is a wide variety of producers, outlets and manufacturers who supply conventional batteries	Yes
High temperature batteries	Long lifespan	Sodium-Nickel batteries are being used to power electrical vehicles	Technologies are costly although expected to decrease with more electrical vehicles being produced with large-scale implementation of NAS batteries.	No
Flow batteries	Long lifespan	Flow batteries are a new technology therefore they are not produced commercially yet	Are portable, have a high level of efficiency but low-density of stored energy, flow batteries are costly	No

1.3 Electromagnetic ES

This form of ES involves using the earth's magnetic field in order to generate and store energy. The energy can either be stored through Capacitors or through a Superconducting Magnetic Energy Storage System (SMES).

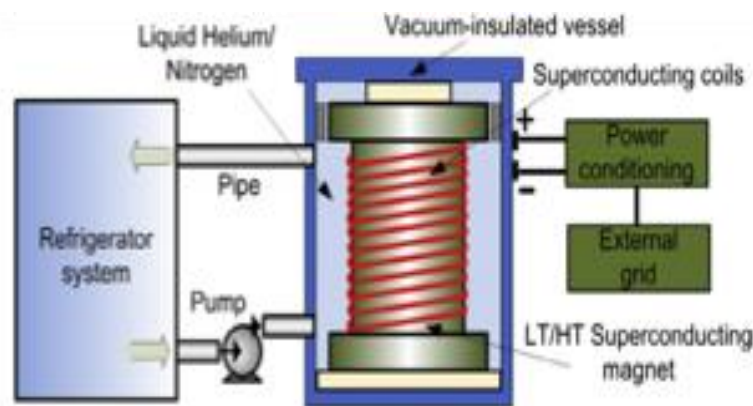
1.3.1 Capacitors

These electrical conductors have been in use since the early 1980's. They are made of material that conducts and stores electromagnetic energy in an electrostatic field (Luo *et al*, 2015). Advantages of this technology include high energy capacity, a long lifespan, durability and low cost and the potential to charge and discharge quickly. One of the drawbacks of using capacitors in ES is the cost of upgrading to larger scale super capacitors which would be needed to address intermittency in renewable energy sources.

1.3.2 Superconducting Magnetic Energy Storage (SMES)

SMES stores energy through direct current (DC). Electrical energy is stored in the magnetic field through a superconducting coil which has been cooled cryogenically. As a consequence of the coil materials and physical conditions within the system no energy is wasted during storage (Luo *et al*, 2015).

Figure 2: Diagram of a SMES system



Source: Luo, X., Wang, J., Dooner, M., Clarke, J., (2015), Overview of current development in electrical energy storage technologies and the application potential in power system operation.

Lou *et al* state "The features of SMES include relatively high-power density (up to 4000 W/L (weight/length ratio), fast response time (millisecond level), very quick full discharge time (less than 1 min), high cycle efficiency (95– 98%) and long lifetime (up to 30 years)" (Lou *et al*, 2015:521).

However, there are some drawbacks in using this technology to solve intermittency mainly due to the high cost of materials and specialist operators required to use the machines. SMES is also a new technology that needs developing for the market place. Therefore this product is not yet market ready.

Table 3: Summary of Electromagnetic ES technologies

Electromagnetic ES categories	Lifespan	Integration	Applicability and scale	Market ready
Capacitors	Long lifespan	Widely integrated	Super capacitors expensive and not widely used	Yes
SMES	Long lifespan	Not widely integrated	High cost of materials and manpower to operate machinery	No

1.4 Chemical and thermal ES

1.4.1 Chemical ES

This technology involves the combustion of natural synthetic gases and hydrogen based gases in a generator or battery. The storage process can be carried out in conventional power plants and refineries. The strengths and drawbacks of each gas ES system are summarised in the table below:

Table 4: Comparison of Chemical ES gas energy storage technologies

<i>Hydrogen chemical storage (H₂)</i>	<i>Synthetic Natural gas chemical storage (SNG's)</i>
<u>Advantages</u> • Hydrogen is an abundant element • Hydrogen chemical storage uses environmentally inert materials • No release of greenhouse gases (GHG's) into the atmosphere	<u>Advantages</u> • Cleaner energy source than most Fossil Fuels • Easy storage both above and below ground • Synthetic natural gas is abundant
<u>Disadvantages</u> • High start-up costs • Fossil fuels are needed for construction and combustion • Dangerous process • Technology is not developed	<u>Disadvantages</u> • Dangerous process with combustible materials • Non-renewable energy source • Releases GHG's into the atmosphere

1.4.2 Thermal ES

This technology uses varying temperatures in order to store energy. The process is either implemented through a cryogenic refrigerator or by an electrical resistor (**Amrouche et al, 2016**). There are three types of thermal ES which are:

- Sensible Heat Storage
- Latent Heat Storage
- Thermo-Chemical Storage

Amrouche *et al* state that “Thermal ES systems can also be used to mitigate the intermittency of renewable energy sources, by storing heat in water tanks, molten salts or another material.” (**Amrouche et al, 2016:20919**).

Thermal Heat Storage Technologies (TES) have been in use commercially since the 1980's (**Rutberg et al, 2013**), the authors also stated that TES is already present in the US market especially in Florida where it is used to cool commercial buildings.

Table 5: Summary of Chemical and Thermal ES technologies

Chemical and Thermal ES categories	Lifespan	Integration	Applicability and scale	Market readiness
Chemical ES	Long lifespan	Not easily integrated	Requires specific production plants	Hydrogen chemical ES – No SNG – Yes
Thermal ES	Medium to long lifespan	Easily integrated	Can be used seasonally	Yes

Section 2: Steps

In the autumn of 2016 The Renewable Energy Association reported that the U.K.'s ES industry was approaching a crossroads with the threat being left behind by more investment in other countries ES industries **(REA, 2016)**.

In order for ES to become more integrated in the UK's electricity grid network, more action needs to be taken from a range of actor's for example UK Government including regulating bodies such as OFGEM, electricity providers, the scientific research community and The National Grid.

2.1 ES and the UK Government

After the UK Climate Change Act (2008) the UK government released the Energy Act (2013) in order to “establish a legislative framework for delivering secure, affordable and low carbon energy including provisions on decarbonisation, reforming the electricity market, reviewing its strategy with OFGEM and introducing new consumer right.” **(Gov.uk, 2013)**.

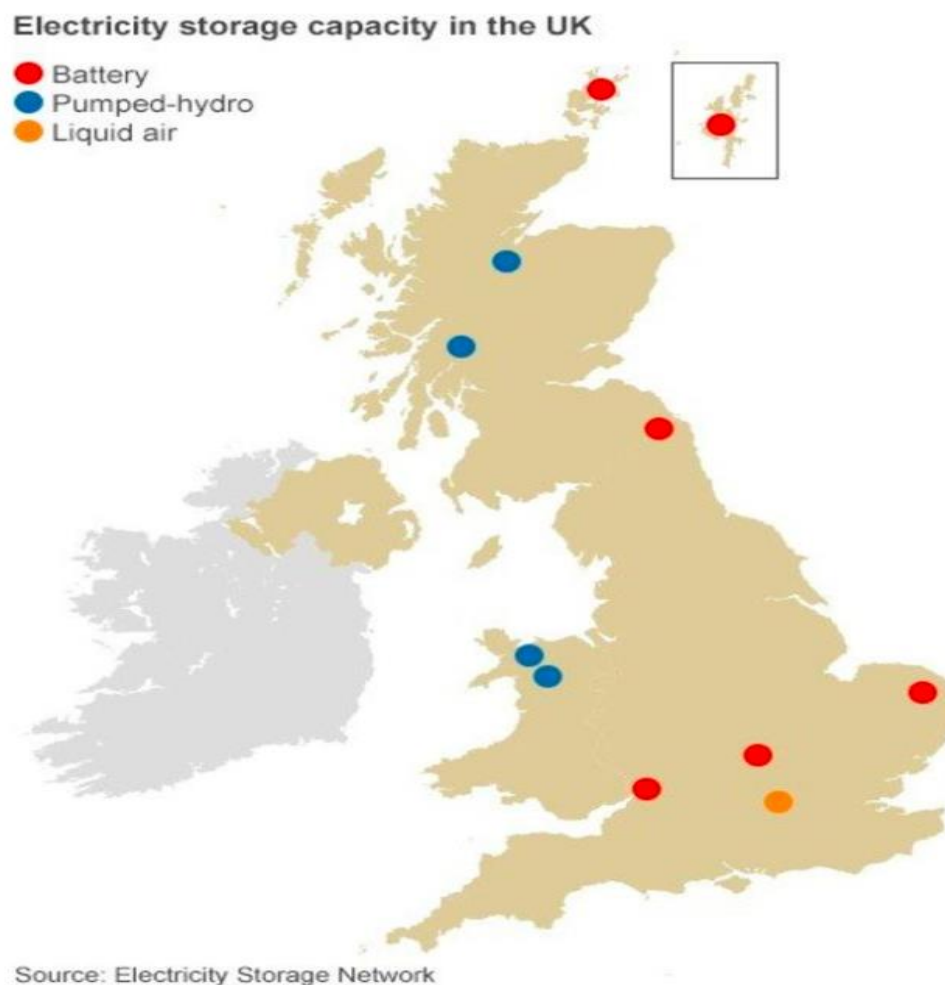
In 2016 the House of Commons reviewed ES in the UK. The Commons summarised its discussion in a report called the ‘Low Carbon Network Infrastructure’. One of it's key suggestions was for the “UK Government to publish its plans for exempting storage installation from balancing charges, and from all double charging of network charges” **(E&CCC, 2016:26)**.

In July 2017, the Government along with its partners committed to invest £70 million into ES between 2018-21 **(Gov.uk, 2017)**. There were also plans for a collaboration with the South Korean Government to invest up to £6 million from 2018-2021 on the development and demonstrations of innovative ES projects.

2.2 Electricity providers and ES

The UK network of electricity providers is currently privately owned. Electricity providers are key actor's in integrating ES into the National Grid system. According to the Renewable Energy Association there were 39 stand-alone ES projects in the UK in 2016 (**REA, 2016**) with the majority of those projects being funded by electricity providers. The Electricity Storage Network has mapped potential new sites for ES projects within the UK for battery, pumped-hydro and liquid Air ES (**Figure 3**).

Figure 3: Electricity Storage Capacity in the UK



Source: BBC website (2014), Energy Storage: The key to a smarter power grid.

There is potential for electricity providers to invest in future ES projects with global ES industries estimated to be worth up to \$100 billion by 2025 (**BBC, 2014**). Energy providers such as French State owned Électricité de France (EDF) have already invested together with other international investors in the UK's nuclear industries such as in Hinkley Point C. A more sustainable option for meeting future energy needs could be met by investing in ES projects rather than in nuclear power.

2.3 Scientific research community and ES

ES energy systems can never reach full efficiency and there will always be energy losses from conversion from an energy source to storage.

As discussed in **section 1** there are many of the forms of ES that are in the early stages of technological development and there is currently no country that implements a network of ES technologies beyond the stand-alone project level. There is a need for more investment in ES research on an international and national level in order to make ES integrated into all new energy developments.

There is one notable example which is the 2014 UK £4 million collaboration between 7 universities and 14 industrial and Governmental bodies created the SUPERGEN ES hub. The hub will develop a shared vision for ES in the future and develop a national roadmap for ES through community engagement (**Ecnmag.com, 2014**).

2.4 The National Grid

There are three concepts which The National Grid could choose to implement into its future infrastructure. They are the concepts of the SMART grid, SuperGrid and MicroGrid.

The SMART grid has been defined as a “bi-directional electric and communication network that improves the reliability, security, and efficiency of the electric system for small to large-scale generation, transmission, distribution and storage” (**Hetzog, 2010**).

Creating a SMART grid would enable energy trade off during peak energy demand and would enable providers to store excess energy during times of low energy demand. The National Grid’s high voltage power transmission network is a dated technology. However the technology and investment needed in order to integrate a SMART grid hasn’t been fully developed and there are no practical examples of a SMART grid on a national scale.

Expanding the existing high-voltage transmission infrastructure and integrating multi state electricity transmission would create a SuperGrid. The SuperGrid has been criticised for not considering the integration of renewable energy in to its network. Contrary to this viewpoint the Friends of the SuperGrid see the concept as a direct current (DC) transmission system designed to transfer mainly renewable energy from remote areas where it is generated to urban centres (**Friends of the SuperGrid, 2010**).

A MicroGrid is where energy is generated and stored on a local scale, for example a single household. This form of energy generation promotes self-sufficiency. With a MicroGrid system energy can be sold back into the grid creating a multi-directional

transmission network. Creating a MicroGrid for the UK would be the most sustainable and effective transmission system.

Table 6: Summary of key actor's and short, medium, and longterm effectiveness

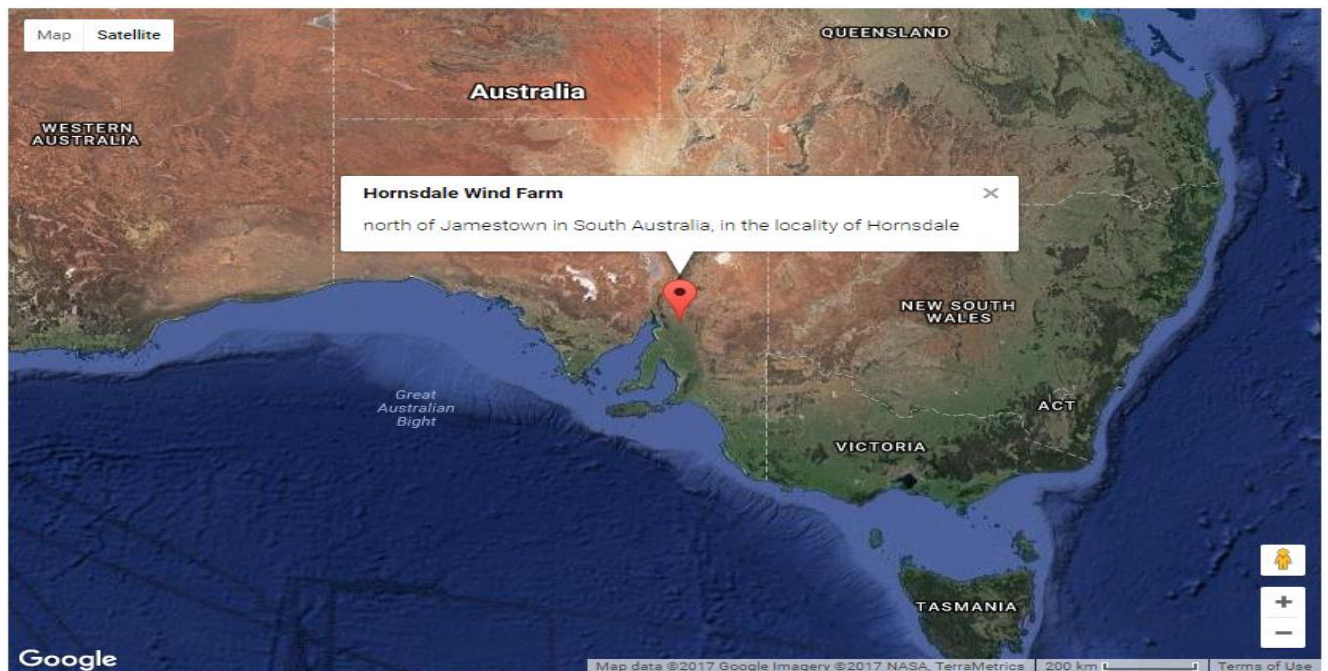
Key actor's	short term effectiveness (0-5 years)	Medium term effectiveness (5-10 years)	Long term effectiveness (+10 years)
UK Government	UK Climate Change Act (2008) Low Carbon Network Infrastructure report (2016) UK Government financial commitment (2017)	There are no apparent steps taken for the medium term	Energy Act (2013)
Electricity providers	Small scale investment in 39 stand-alone ES projects	There are no plans for medium term investment currently	Potential investment in Pumped-Hydro, Liquid Air and Battery ES
Scientific research community	Much published research with short term investment	Medium term research programmes are in development	SUPERGEN ES hub (2014)
The National Grid	No change in current provision	The SuperGrid	The MicroGrid, The SMART Grid

Section 3: A case study of ES in Jamestown, South Australia

3.1 Background

In December 2017 through a collaboration between Tesla, Neon (*French energy provider*) and The South Australian (SA) Government, the world's largest Lithium-ion battery was installed near Jamestown, SA. The purpose of the installed 100MW - 129MW battery (**Greycellsenergy.com, 2017**) was to mitigate against blackouts caused by extreme weather in the region through providing stored energy when needed (**bbc.co.uk, 2017**).

3.2 Location



source: www.gozmodo.com.au (2017), All the details on Tesla's Giant Australian battery.

3.3 Discussion

Australia is still dependant on fossil fuels for energy production with over two thirds of its total energy production coming from fossil fuels in 2015 (**Originenergy.com.au, 2015**). In September 2016 a storm surge left over 1.7 million residents in South Australia without power and led to a state-wide blackout. The South Australian Government had no choice but to draw energy reserves from nearby State of Victoria.

The limited energy security of South Australia presented an opportunity for Tesla's CEO and founder Elon Musk who famously promised that the Lithium-Ion battery complex would be built within 100 days otherwise he would build it for free. The battery was built in 60 days. The battery's renewable energy supply comes from the Hornsdale wind farm located adjacent to the battery complex and would generate enough ES to power 30,000 homes (**bbc.co.uk, 2017**).

This report will now examine some of the criticisms of the project. The battery only has capacity for 100MW-129MW of electricity output, and was designed as a backup energy supply when energy is short. However some politicians have criticised the function of the battery for example Liberal MP Craig Kelly has criticized the efficiency of the power generation stating that it would require "30 batteries complexes of similar size to power South Australia on a hot day for 79 minutes" (**Kelly. C, 2017**).

The project has been also labelled a public relations stunt used by Tesla to promote its products within the Australian market. The project has also been criticised for the costs of installation with estimated costs around \$50 million dollars.

There is currently insufficient published data to quantify the success of the Tesla installation at this stage due to its newness. Although data has been published by the Australian Energy Market Operator (AEMO) that suggests the battery is surpassing expectations by responding quickly to energy outages (blackouts) (**Theconversation.com, 2018**). The Victorian State has also planned to build its own Lithium-Ion battery complex in the town of Stawell.

This case study was chosen because of a personal interest in Australian ES. It would be interesting to see how the UK market will respond to this innovation and apply the technology to UK energy consumers.

Conclusion

There has been an increased interest and uptake of renewable technologies during recent years stimulated by international policies and agreements.

However intermittency within certain renewable energy sources is a barrier to achieving universal energy security. This report has analysed how energy storage could be a possible solution to solve intermittency. It has also examined how ES is integrated in the UK.

The following recommendations have been made in order to solve intermittency issues in the UK.

Recommendations

1. Affordable and efficient ES needs to be available for all renewable energy sources
2. Clear guidance needs to be issued by the UK Government on what is effective ES
3. It should be compulsory that all new built houses and commercial buildings incorporate ES into their design
4. ES needs to be integrated into a MicroGrid
5. Enhanced research and investment needs to be put into ES technologies

(Words excluding figures and tables 3001)

References

Akinyele, D. and Rayudu, R. (2014). Review of energy storage technologies for sustainable power networks. *Sustainable Energy Technologies and Assessments*, 8, pp.74-91.

Amrouche, O, S., Rekioua, D., Rekioua, T., Bacha, S., 2016. Overview of energy storage in renewable energy systems. *International Journal of Hydrogen Energy* 41, 20914–20927. doi:10.1016/j.ijhydene.2016.06.243

BBC news website (2014), Energy Storage: The key to a smarter power grid. [online] Available from <http://www.bbc.co.uk/news/business-27071303> [accessed 15 April 2018].

BBC news website (2017), Tesla mega-battery in Australia activated. [online] Available from <http://www.bbc.co.uk/news/world-australia-42190358> [accessed 15 April 2018].

Blarke, M.B., Jenkins, B.M., 2013. SuperGrid or SmartGrid: Competing strategies for large-scale integration of intermittent renewables? *Energy Policy* 58, 381–390. doi:10.1016/j.enpol.2013.03.039

Boise State University (2007). Overview of Compressed Air Energy Storage. [online] Office of Energy Research, Policy and Campus Sustainability, pp.1-4. Available at: <https://www.necec.org/files/compressedair.pdf> [accessed 10 Apr. 2018].

Demirbaş, A., 2006. Global renewable energy resources. *Energy Sources, Part A: Recovery, Utilization and Environmental Effects* 28, 779–792. doi:10.1080/00908310600718742

Díaz-González, F., Sumper, A., Gomis-Bellmunt, O., Villafáfila-Robles, R., 2012. A review of energy storage technologies for wind power applications. *Renewable and Sustainable Energy Reviews*. doi:10.1016/j.rser.2012.01.029

Eight Great Technologies Energy Storage Intellectual Property Office is an operating name of the Patent Office A patent overview. (2014). [online] Newport: UK Intellectual Property Office Informatics Team. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/359299/informatics-energy.pdf [Accessed 8 May 2018].

Electronic Component News (2014), New SUPERGEN Hub to set UK's energy storage course. [online] Available from <https://www.ecnmag.com/news/2014/05/new-supergen-hub-set-uks-energy-storage-course> [accessed 21 April 2018].

Energy and Climate Change Committee, Low Carbon Network Infrastructure, 17 June 2016, HC 267 2016-17: page 26

Foley, A.M., Leahy, P.G., Li, K., McKeogh, E.J., Morrison, A.P., 2015. A long-term analysis of pumped hydro storage to firm wind power. *Applied Energy* 137, 638–648. doi:10.1016/j.apenergy.2014.07.020

Friends of the SuperGrid, 2010. Position Paper on the EC Communication for a European Infrastructure Package

Gizmodo website (2017), All the details on Tesla's Giant Australian battery. [online] Available from <https://www.gizmodo.com.au/2017/07/all-the-details-on-teslas-giant-australian-battery/> [accessed 30 April 2018].

Greycells energy website (2017), The Tesla “big battery” (South Australia). [online] Available from <https://greycellsenergy.com/examples/the-tesla-big-battery-south-australia/> [accessed 10 April 2018].

Hadjipaschalis I, Poullikkas A, Efthimiou V. Overview of current and future energy storage technologies for electric power applications. *Renewable and Sustainable Energy Reviews* 2009;13:1513–22.

Hardisty, J., 2008. Power intermittency, redundancy and tidal phasing around the United Kingdom. *Geographical Journal* 174, 76–84. doi:10.1111/j.1475-4959.2007.00263.x

Hertzog, C., 2010. *Smart Grid Dictionary*, second Ed

International Electrotechnical Commission (2011). *Electrical Energy Storage*. [online] Geneva: International Electrotechnical Commission, pp.1-79. Available at: <http://www.iec.ch/whitepaper/pdf/iecWP-energystorage-LR-en.pdf> [accessed 15 Apr. 2018].

Luo, X., Wang, J., Dooner, M., Clarke, J., 2015. Overview of current development in electrical energy storage technologies and the application potential in power system operation. *Applied Energy* 137, 511–536. doi:10.1016/j.apenergy.2014.09.081

Maton, J., Zhao, L. and Brouwer, J. (2013). Dynamic modeling of compressed gas energy storage to complement renewable wind power intermittency. *International Journal of Hydrogen Energy*, [online] 38(19), pp.7867-7880. Available at: <https://cloudfront.escholarship.org/dist/prd/content/qt9t31320h/qt9t31320h.pdf> [accessed 1 May 2018].

Origin Energy website (2015), Energy in Australia. [online] Available from <https://www.originenergy.com.au/blog/about-energy/energy-in-australia.html> [accessed 11 April 2018].

Renewable Energy Association (2016). *Energy Storage in the UK an Overview*. [online] Renewable Energy Association, pp.4-29. Available at: https://www.r-e-a.net/.../REA_-_Energy_Storage_in_the_UK_Report_2016_Update.p... [Accessed 3 May 2018].

Rutberg, M., Hastbacka, M., Cooperman, A., & Bouza, A. (2013). Thermal Energy Storage. *ASHRAE Journal*, 55(6), 62,64,66.

Sovacool, B. (2009). The intermittency of wind, solar, and renewable electricity generators: Technical barrier or rhetorical excuse?. *Utilities Policy*, 17(3-4), pp.288-296.

The Conversation website (2018), A month in, Tesla’s SA battery is surpassing expectations. [online] Available from <https://theconversation.com/a-month-in-teslas-sa-battery-is-surpassing-expectations-89770> [accessed 29 April 2018].

The Daily Mail website (2017), Elon Musk says Tesla is halfway to producing the world's biggest battery in Australia after promising to give it for FREE if it's not done in 100 days. [online] Available from <http://www.dailymail.co.uk/sciencetech/article-4940234/Elon-Musk-halfway-producing-biggest-battery-Australia.html> [accessed 8 April 2018].

The Guardian Online (2018), Subsidy-free renewable energy projects set to soar in UK, analysts say. [online] Available from <https://www.theguardian.com/business/2018/mar/20/uk-subsidy-free-renewable-energy-projects-set-soar-aurora-energy-research-analysts> [accessed 13 April 2018].

Trainer, T. (2017). Some problems in storing renewable energy. *Energy Policy*, 110, pp.386-393.

U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy website. How hydropower works. [online] Available from <https://www.energy.gov/eere/water/how-hydropower-works> [accessed 24 April 2018].

UK Government website (2013), Energy Act: The Energy Act received Royal Assent on 18 December 2013. [online] Available from <https://www.gov.uk/government/collections/energy-act> [accessed 13 May 2018].

UK Government website (2017), Funding for innovative smart energy system. [online] Available from <https://www.gov.uk/guidance/funding-for-innovative-smart-energy-systems> [accessed 11 May 2018].

Van Kooten, G. (2009). Wind power: the economic impact of intermittency. *Letters in Spatial and Resource Sciences*, 3(1), pp.1-17.

Walrus Rider, 2017. Is Elon Musk's Huge Battery in South Australia A Huge Waste of Money? (2017). [online video] Available at <https://www.youtube.com/watch?v=vgOgW0IEWeg> [accessed 19 April 2018].