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European Union
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Energy Storage Market Report

Low Carbon Network Report

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Prepared for **Business Growth Hub** by **Regen**

Business Growth Hub - Energy Storage Market Research Report

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Photo credit: AES

Contents

1. Introduction

The last 18 months has seen a huge increase in the level of interest in energy storage in the UK. In part, this is being driven by the major transition that is underway in the UK energy market, with a move from a largely centralised to a much more decentralised energy system. The decentralisation of energy generation is in turn creating higher value opportunities for technologies that can provide flexibility and support local energy supply.

In part, this surge of commercial interest has been driven by:

- The reduction, and continued fall, in energy storage costs
- The availability of high value revenue streams for balancing and ancillary services through the procurement of Enhanced Frequency Response and the Capacity Market
- The parallel slowdown in development of renewable energy (onshore wind and solar PV) which means that resources and capital are available for new opportunities

At the large scale, the Enhanced Frequency Response and the Capacity Market auctions have brought forward a large number of potential projects across the Manchester study area (see Figure 1), including 12 bids in total and four successfully winning Capacity Market contracts (two in Greater Manchester).

At the domestic and commercial scale, there have been some significant announcements and investment, but the market is still building momentum.

There are a number of leading energy storage companies in the Manchester area, which are primed to benefit significantly from the growth of energy storage. This is particularly noteworthy for the domestic energy storage market, which is at an early stage of development.

Manchester is now known to be a hub for the energy storage market. SME's should be aware of and develop the opportunities in this rapidly growing sector to maximise the economic benefit for the area.

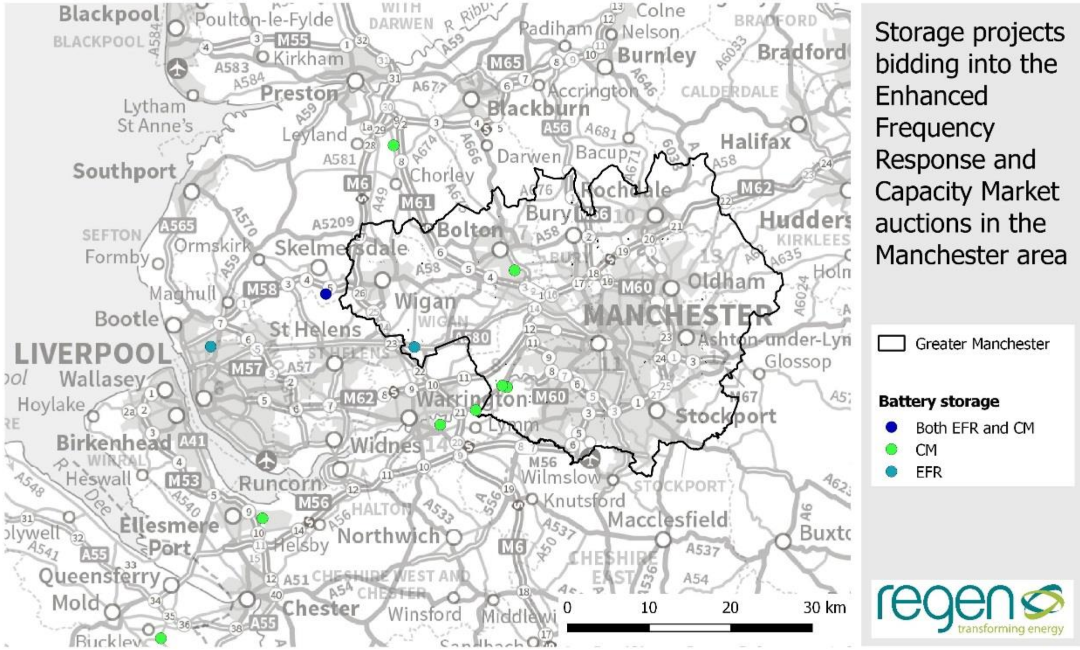


Figure 1: Energy storage projects bidding into Capacity Market (CM) and Enhanced Frequency Response (EFR) auctions in Greater Manchester and the study area

1. Why energy storage and why now?

Energy storage is a dominant topic of interest in the energy sector. What commercial models can be applied? How much will be installed? When and where will it be deployed? These are all key questions the sector is grappling with and we will be covering in this report.

As an introduction to the area of energy storage it is useful to understand a little more about the energy system in the UK and the pace of change.

1.1 A changing energy system

Our energy system has changed and continues to evolve. Over the last few decades we relied on around 10 large power stations, but now we have almost a million generators of energy at a variety of scales. This change from a centralised to decentralised energy system is nothing short of a revolution in how, when and where we generate energy.

Most of this new decentralised generation is in the form of renewable energy generation, which is variable[1]. This means we are reliant on when there is wind and sun to generate energy. This is a significant change from the fossil-fuel based generation (mostly gas and coal), which can be turned up and down when we need it.

At the same time, many of our large power stations have closed or are due to close. The government has indicated they want to phase out all coal use by 2025[2] and three large coal-fired power stations closed in 2016. Our nuclear power stations are at the end of their working life, with some replacements planned.

We will need more generation capacity, with the majority to come from gas and renewables. The question is how much and to what degree this is blended with new sources of flexibility?

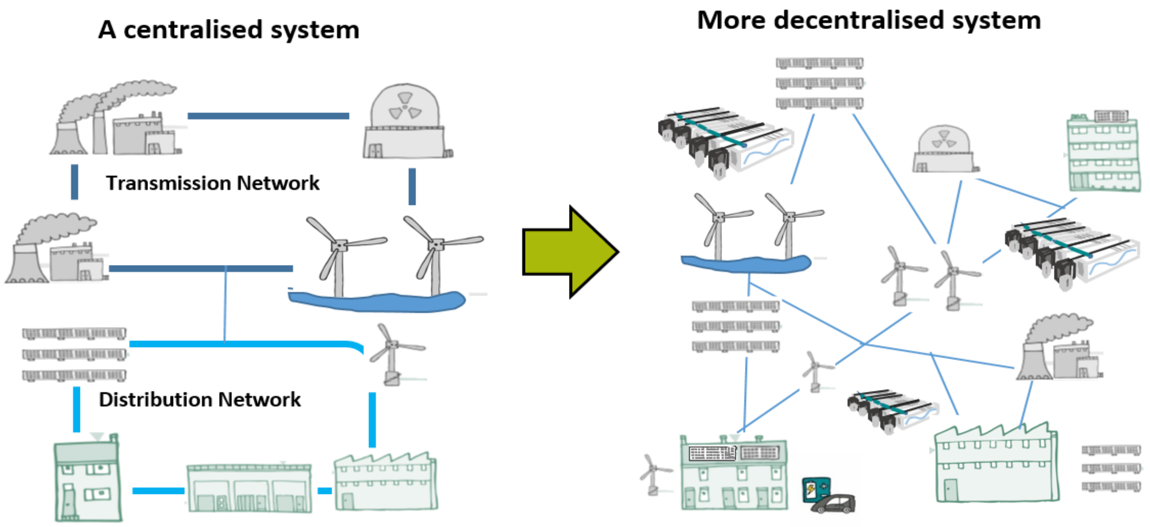


Figure 2: The shift from a centralised to a decentralised energy system, with more generators, flexibility and interconnection.

[1] Variability in this case refers to the amount of generation going up and down. There are non-variable sources of renewable energy, such as Anaerobic Digestion (AD), but they are less common.

[2] New direction in energy policy, 2015 https://www.gov.uk/government/news/new-direction-for-uk-energy-policy

1.2 The need for flexibility

Instead of building lots of new power stations, and the associated network infrastructure, we have the option to use sources of flexibility to meet the peaks in energy demand we experience. These occur mainly in the morning and evening, and are much bigger in the winter. There are a few main sources of flexibility available (Figure 3), with energy storage getting the most attention.

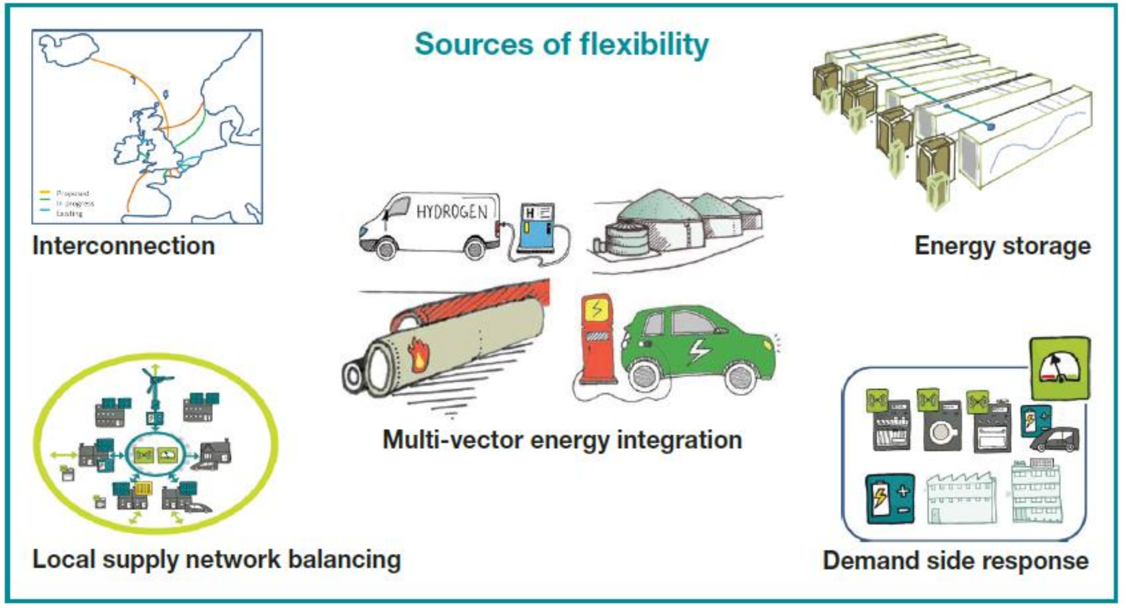


Figure 3: A selection of the main sources of flexibility in the UK energy system

The value of flexibility is significant. The government estimates the benefits from a smart and flexible energy system to be £17-40 billion up to 2050[3]. With the flexibility market starting to blossom - 3 GW of new flexibility contracted since 2016 – there is significant opportunity and growth in this sector. In the smart systems and flexibility plan, released by government and Ofgem (the regulator) in July 2017, they state that, 'newer forms of flexibility face barriers that may inhibit their development. We believe that the key to overcoming these barriers is ensuring there are open and transparent **markets which work for flexibility**.'

Regen and others have emphasised that although energy storage is well placed to provide flexibility services to the market, it is competing against other technologies that are currently cheaper (e.g. demand side response)[4]. This should temper the ambitious projections for energy storage growth to a degree. However, the cost reduction evident over the last few years and predicted moving forward, will "tip the scales" in favour of energy storage.

[3] Ofgem/BEIS, 2017 https://www.ofgem.gov.uk/system/files/docs/2017/07/upgrading_our_energy_system_-_smart_systems_and_flexibility_plan.pdf

[4] EASAC, 2017 http://www.easac.eu/fileadmin/PDF_s/reports_statements/Electricity_Storage/EASAC_Electricity_Storage_Full_Report.pdf

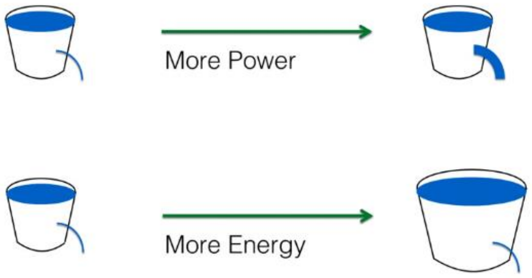
2. What is energy storage?

Energy storage allows the shifting of energy delivery from a time when it is less valuable, to a time when it is more valuable, either to the consumer or to the network.

Energy storage is not new, technologies such as pumped hydro, flywheels, and heated water tanks have been in use for several decades. However, it does have a different set of technical characteristics and definitions in comparison with more established generation technologies.

Both the power rating and energy capacity, dictate how long and at what rate, the electricity storage project can export to the network or import to the device. A useful analogy is a bucket of water, with the size of the bucket representing the energy capacity and the size of the hole representing the power rating (see below).

Alongside the energy capacity many energy storage systems can only discharge down to a certain level. This means that an energy storage system has a usable capacity (in kWh), that is smaller than the overall energy capacity stated.



The way in which the electricity storage device is used can have an impact on its lifetime.

Key definitions:

- **Kilowatt** (kW) – is the most common unit used to measure energy delivery. A kilowatt is a thousand watts. A Megawatt (MW) is a thousand kilowatts (kW).
- **Kilowatt hour** (kWh)- is the most common unit used to measure energy delivery over a period of time. One 100 Watt bulb on for 1 hour consumes 0.1 kWh. A Megawatt hour (MWh) is a thousand kilowatt hours (kWh).
- **Power rating** (kW/MW) – the power rating is the peak power a storage device can deliver.
- **Energy capacity** (kWh/MWh) - how much energy the device can store and delivery over time.
- **Cycle or round-trip efficiency** (%) – this is the ratio between the amount of power put in to a storage device and the amount you get back out. There are normally some losses in this process, which vary depending on the technology.
- **Lifetime** (years or charge-discharge cycles) – the length of time the electricity storage project lasts. This is technology specific and varies considerably depending on how the storage device is used.
- **Response time** (milliseconds to minutes) – how fast the electricity storage can react to a signal and start exporting/importing to the network.

2.1 Energy storage types and technologies

Energy storage encompasses a whole range of technologies. Broadly they can be classified as chemical, electrical, thermal, electrochemical and mechanical. Within these classifications there are a number of technologies (see Figure 4). All have various benefits and drawbacks which need to be taken into account when assessing a potential project.

Pumped Hydro - by capacity, more than 99 per cent of global energy storage is made up of large scale pumped hydro projects. This is where water is pumped up to a top reservoir of water and then let down the hill to a bottom reservoir, through a turbine to create electricity. This is utilised as core grid balancing infrastructure in traditional centralised energy systems.

Flywheels – this works by storing electricity as kinetic energy using the rotation of a heavy disk or rotor in a vacuum**.** When this is slowed it produces electricity in a very short time (milliseconds). Europe's largest hybrid flywheel battery project is due to be installed at the University of Sheffield[5].

Compressed Air Energy Storage (CAES) - globally, there are currently six large scale CAES projects (more than 100MW combined power output)[6]. This includes the 330 MW Gaelectric project, which has been announced for completion in 2017 using subterranean salt caverns in Larne, Northern Ireland. Further projects have been proposed utilising salt seams in the north west and southern England. The technology compresses air using electricity and stores it in above ground or underground vessels. A local example of a related technology, liquid air energy storage (LAES) is given below. This technology is at an early stage of development but could become more significant in the bulk energy storage market.

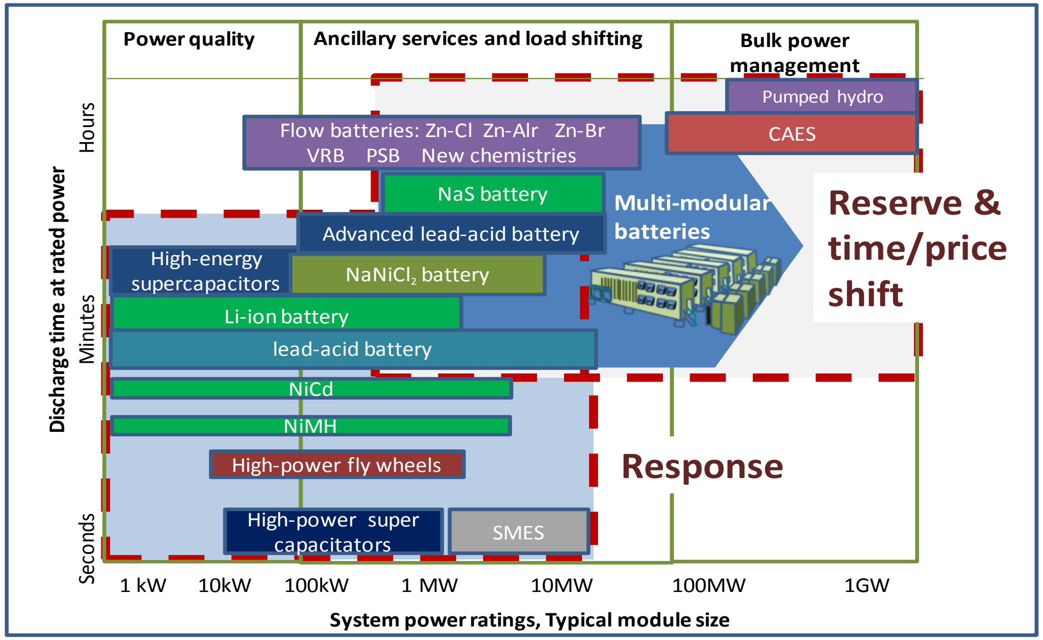


Figure 4: A diagram depicting the different energy storage technologies with scale, discharge time and applications

Hydrogen – you can convert electricity into hydrogen by electrolysis. This can then be stored and converted back to electricity when required. The round-trip efficiency is low (30-40%) and the technology is expensive currently, however, the potential for the technology to provide long term, large scale energy storage is significant. The lower efficiency is a result of the technology still being in the demonstration/early commercialisation phase and the limitations of the current electrolysers and fuel cell chemistries available.

A hydrogen cluster is planned for the Liverpool and Manchester area[7]. This innovation project will look at supplying significant industrial users and adding hydrogen to the gas distribution network.

[5] University of Sheffield, 2017 https://www.sheffield.ac.uk/news/nr/flywheel-europe-energy-1.704921

[6] US Department of Environment – Energy Storage Database Aug 2016 data

[7] Cadent, 2017 http://cadentgas.com/About-us/Innovation/Projects/Liverpool-Manchester-Hydrogen-Cluster

Supercapacitors – are similar to batteries and operate in instances where energy needs to be accepted and delivered rapidly. They have a lower energy capacity and a high-power output.

One of the key applications of supercapacitors is there use in hybrid energy storage solutions with other technologies (see right).

Highview Power - Liquid Air Energy Storage

A liquid air energy storage (LAES) located in Bury, Greater Manchester has received £1.5 Million of Innovate UK funding, to add supercapacitors and flywheels to their existing 5MW/15MWh pre-commercial demonstration plant (at project partner, Viridor's, Pilsworth landfill gas plant). This project is a world leading example of the technology.

LAES works by liquifying gases at a very low temperature and then releasing the gas through a turbine. LAES can provide low cost, large scale, fast response (minutes), long duration (hours to weeks) energy storage using existing technology and integrating waste heat (or cooling) from other sources.

A standalone project has a lower round-trip efficiency than other storage technologies (50-60%). Mainly due to lost heat and cooling during the air liquification process. However, integration of waste heat and/or cooling improves performance (70%+).

www.highview-power.com/

Battery storage

Lithium-Ion – is by far the dominant technology, making up 83% of installed capacity in 2016 (excluding pumped hydro)[8]. There are variations of battery chemistries that come under the term Lithium-Ion, which simply refers to the transfer of lithium ions between electrodes.

Having started in consumer electronics, the technology has been dominant in the Electric Vehicle (EV) market, allowing more large-scale manufacturing and a huge reduction in cost (down 50% since 2012). With the Tesla Gigafactory starting production of battery cells in early 2017 (in collaboration with Panasonic)[9], and at least one Tesla Gigafactory factory planned for Europe, costs will continue to tumble as manufacturing levels rise. The manufacturing base is starting to increase in the UK, with Nissan in Sunderland for their Nissan Leaf and xStorage products[10] and the announcement of the Industrial Strategy Challenge Fund “Batteries for Britain” funding[11].

Flow batteries – use two different electrolyte liquids, normally separated by a membrane. The energy density can be lower than other energy storage technologies, but the lifetime is long with little reduction in performance.

This battery type is not used in other consumer areas. Subsequently the manufacturing base is much more limited. However, due to the higher current price and technology improvements predicted, the forecast cost savings are proportionally comparable to Lithium-Ion[12].

A 1 MWh flow battery has been installed in Cornwall, alongside 350kWp of solar PV on a holiday park. RedT are the manufacturer and it is due to be used in the £19 million Centrica Local energy market project[13].

Lead acid – an established technology, they are widely used in stationary applications. The batteries are low cost, but can require maintenance and have a limited lifetime. This is due to the current chemistry and the corrosion that can form on the battery plates.

The classic use of this technology is in car batteries, but it has also been used in remote locations with renewable energy for decades.

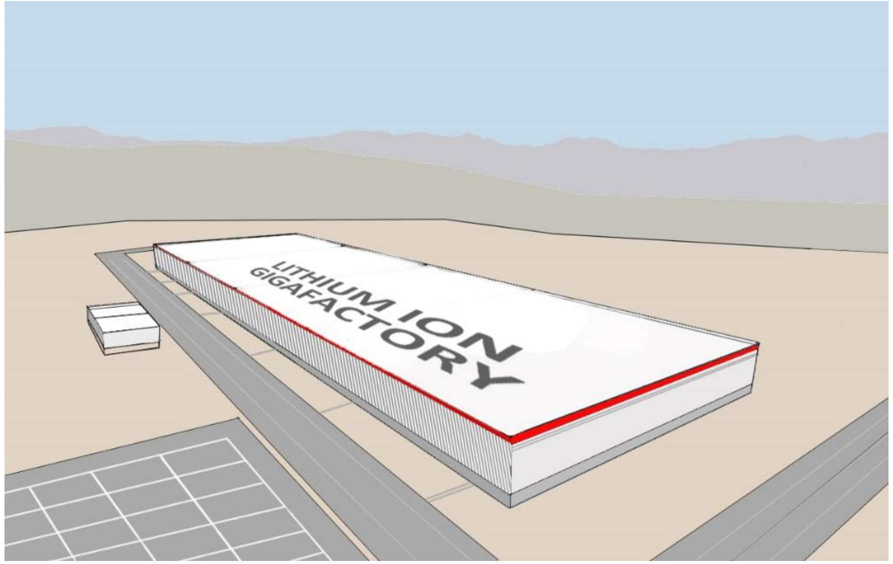


Figure 5: Illustration of the Tesla Gigfactory in Nevada, USA.

[8] Navigant research, 2016 http://www.navigantresearch.com/research/energy-storage-tracker-3q16
[9] Tesla, 2017 https://www.tesla.com/blog/battery-cell-production-begins-gigafactory
[10] Nissan, 2017 http://nissaninsider.co.uk/made-in-britain-the-new-nissan-leaf-with-more-than-100-updates/
[11] EPSRC, 2017 https://www.epsrc.ac.uk/funding/calls/iscffaradaychallengebatteries/
[12] IRENA, 2017 https://costing.irena.org/media/11341/2017_Kairies_Battery_Cost_and_Performance_01.pdf
[13] redT, 2017 http://www.redtenergy.com/blog/redt-largest-cornwall-project

Table 1: An overview of the main energy storage technologies

Main energy storage technologies[14]				
Storage class	**Technology type (examples)**	**Typical technology attributes**	**Cycle efficiency**	**Response time**
Chemical	• Hydrogen • Synthetic natural gas	• Medium to large scale • Multi vector – power, heat & transport • Transferability	30-45%	10 minutes
Electrical	• Supercapacitors • Super conducting magnetic storage	• Very fast response times • High efficiencies	90-94%	Milliseconds
Thermal	• Molten salt (Heat/CSP thermal) • Packed bed heat storage • SETS	• Multi-vector to heat	30%	Seconds to minutes
Electrochemical **Solid state** **Flow state**	• Lead/acid • Lithium-ion, Lithium-S, Lithium-polymer • Sodium-ion, Sodium-sulphur(NaS) • Nickel-cadmium • Vanadium redox, Zinc bromide	• Small to medium scale • Scalability – modular units • Very fast response times • Rapid charge capability	75-95% 60-75%	Milliseconds
Mechanical	• Flywheels • Compressed Air Energy Storage (CAES) • Pumped heat electrical storage • Pumped hydro	• Large scale • Long discharge periods	80-87%	Instantaneous to seconds/minutes

[14] Regen, 2016 https://www.regensw.co.uk/storage-towards-a-commercial-model

2.2 Commercial business models

At a high-level energy storage performs three main roles within the electricity network:

- **Response:** The ability to respond quickly (milliseconds – minutes) to grid, frequency and/or price signals. Potential applications include the provision of ancillary network services such as frequency response and voltage support.
- **Reserve:** The fundamental property of energy storage that enables the storage of energy to be used at a time when it is required. From a simple back-up capability for use as an alternative source of energy, to large scale capacity reserve and Short Term Operating Reserve (STOR).
- **Price and time shift:** The capability to shift energy from lower to higher price/cost periods. A more sophisticated application of both reserve and response functions, allowing energy users and suppliers to take advantage of price variance (price arbitrage), avoid peak transmission and distribution costs and/or to recover energy that would be lost due to network or other constraints.

The variation in business models will determine how electricity storage solutions are designed and the operating mode of how they are used. This includes the ratio between MW power and MWh storage capacity, the depth of discharge and the periods of charge/import and discharge/export. Since the business models and their variations will determine how storage will evolve in the UK market - we list some examples below.

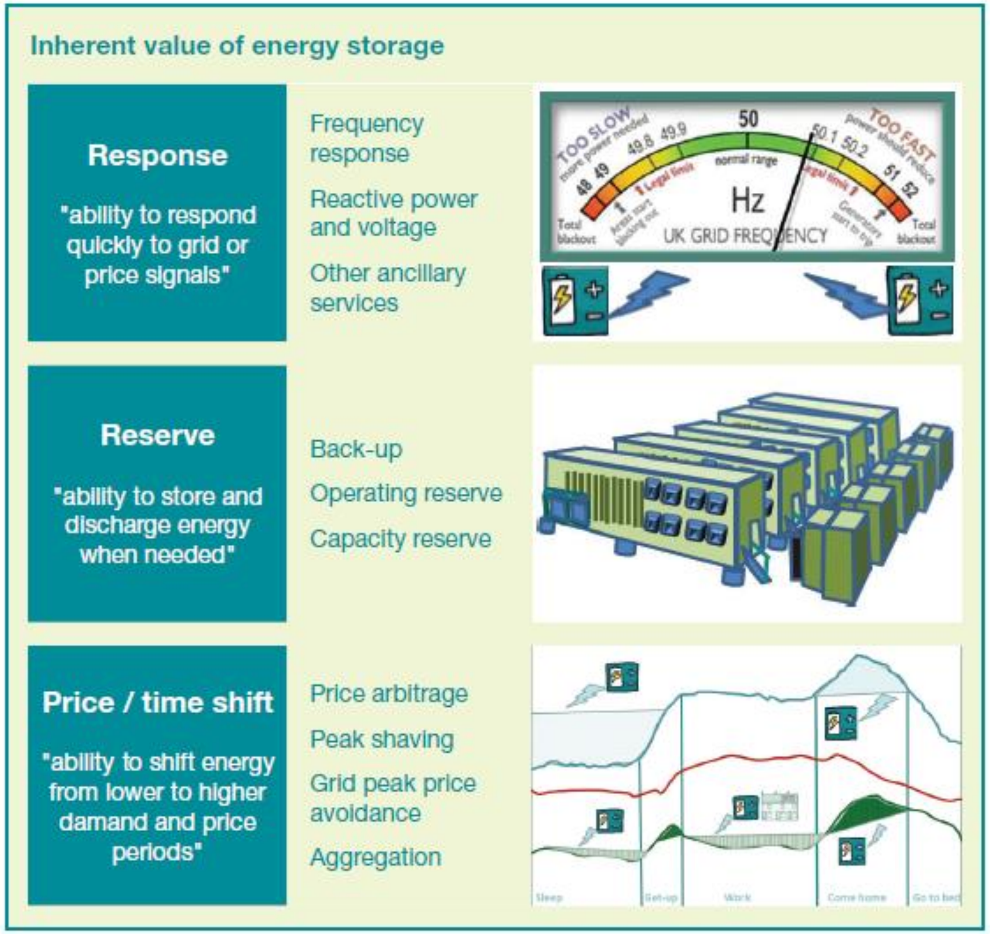


Figure 6: An illustration of the main roles of energy storage

Regen has developed a list of what we currently consider to be the most likely emerging business models:

1. **Response service -** Providing higher value ancillary services to transmission and distribution network operators, including frequency response
2. **Reserve service -** Specifically aiming to provide short/medium term reserve capacity for network balancing services
3. **Commercial and industrial -** Located with a higher energy user (with or without on-site generation) to avoid peak energy costs, and peak transmission and distribution network charges while providing energy continuity
4. **Domestic and community -** Domestic, community or small commercial scale storage designed to maximise own use of generated electricity and avoid peak electricity costs
5. **Generation co-location -** Storage co-located with variable energy generation in order to: a) price/time shift or b) peak shave to avoid grid curtailment or reinforcement costs
6. **Energy trader -** The business model that references the potential for energy supply companies, local supply markets and/or generators using storage as a means of arbitrage between low and high price periods - likely aggregated - and peak shaving.

	Response Service	High energy user - cost avoidance	Domestic and community	Energy reserve	Energy trader
Primary service	Enhanced Frequency Response* or FFR	Transmission cost avoidance	Generator "own use"	STOR* or Fast Reserve or Capacity Market	Price arbitrage and peak shaving
Additional revenue(s)	Firm Frequency Response	Distribution cost avoidance	Aggregated "own use"	Transmission cost avoidance	Aggregated price arbitrage
	Transmission cost avoidance	Peak shaving	Price arbitrage and peak shaving	Distribution cost avoidance	Grid curtailment
	Distribution cost avoidance	Frequency control by demand management	Grid curtailment	Price arbitrage and peak shaving	
	Capacity market**	Generator "own use"	Frequency Response*		
		Backup	STOR* or Capacity Market		

*Note – there are timing constraints which would prevent several grid response and reserve services being provided simultaneously, so different service time periods would be required

**If frequency response is defined as 'relevant balancing service'

Figure 7: An illustrative graphic of how revenues can be 'stacked' to make a viable business model

2.3 Enabling technologies for energy storage

In order for energy storage to be viable, a number of components and technologies need to come together to create a successful project. These systems can be complex and require considerable time and effort to develop. For example, the data and control capability of a given project is fundamental to an efficient and worthwhile system that can access and deliver services. If a given project needs to access different income streams, there needs to be sufficient charge available to deliver when required and an ability to prioritise between services.

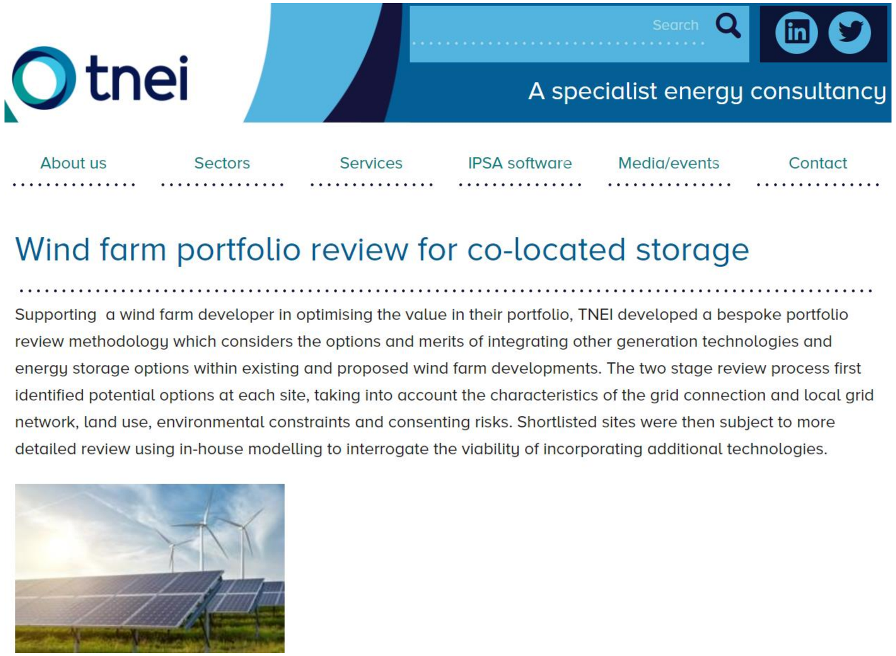
The key enabling technologies are listed below:

- Metering
- Software/control systems
- Forecasting/optimisation packages
- Power conversion (inverters/transformers)
- Battery cells (or other energy storage type)
- Aggregator/market platforms.

The UK Power Networks Smarter Network Storage innovation project[15] has provided an overview of the main components of the operational design of a large grid scale battery (see Figure 8). Although this is at the extreme end of the complexity scale, even domestic energy storage systems will want to integrate most of the components/technologies listed. Specialist SME's, such as installers and energy consultancies, are well placed to deliver the technical expertise needed for the delivery of energy storage projects.

Case study – TNEI group

A number of SME's are active as consultancies in the energy sector in Manchester. The Northern Energy Initiative (TNEI) was first created at the University of Manchester and now provides technical, strategic, environmental and consenting advice to organisations operating within the conventional and renewable energy sectors. They have completed work in the energy storage sector and are well placed to continue to do so.



https://www.tneigroup.com

[15] UKPN, 2015 http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Smarter-Network-Storage-(SNS)/

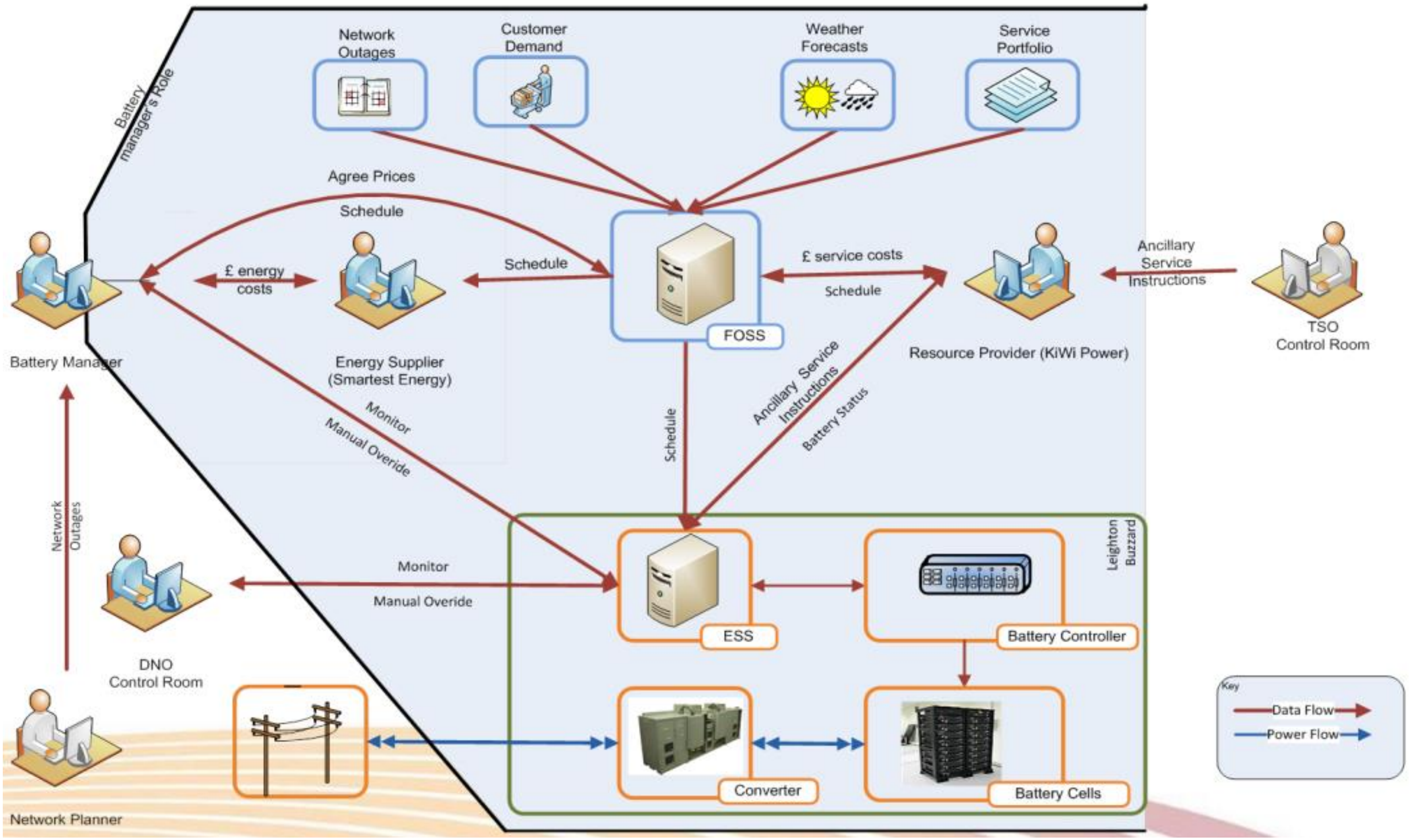


Figure 8: Graphic of the control/optimisation architecture of the Smarter Network Storage UK Power Networks innovation project. This graphic provides an overview of the data flows (red arrows) and power flows (blue arrows) between the different aspects of the project. The Forecasting, Optimisation and Scheduling System (FOSS) has a central role in the operation, taking in various inputs and scheduling the discharge and charge of the Energy Storage System (ESS). The energy supplier, resource provider and battery manager need to manage the energy storage to deliver the services they have contracted to provide. This could be for the Transmission System Operator (TSO) (National Grid) or perhaps in the future for the Distribution Network Operator (DNO) (e.g. Electricity North West). The overall picture presented is that the control and operation of an energy storage project is complex and requires a number of parties.

3. What are the market drivers for energy storage?

There are a number of critical drivers which are encouraging commercial interest in storage projects. Amongst these we would highlight:

- the inherent need for greater flexibility in our future energy system and the growth of variable generation
- the current and anticipated fall in storage costs and the cost of enabling technologies
- new technologies for storage and enabling technology
- the market for new flexibility services
- anticipated regulatory changes
- the level of competition for balancing, flexibility and price arbitrage services which may come from interconnectors, DSR and existing generators.

Interestingly, and perhaps uniquely for a new technology in the energy market, energy storage projects do not benefit from a specific subsidy support mechanism. A key challenge therefore is for storage projects to develop a business model which is sustainable and robust enough to attract investment, without the benefit of long-term government-backed security (such as the 20 year Feed-in Tariff for renewable energy). This means looking at potential revenue streams in combination (revenue stacking) and the ability to fully utilise an energy storage asset value potential.

The recent consultation on a new System Needs and Product Strategy (SNAPS)[16] from National Grid provides a view on how the energy storage market could develop. One of the key points to takeaway is that there is significant uncertainty about the size of the future market, illustrated by the large range of values given. There is also an acceptance from National Grid that the twenty complex products currently offered need to be simplified. One certainty is that there is growing need for flexibility services, but the consultation asks some big questions that the sector is grappling with:

- How long will contracts be for?
- What procurement methods will be used?
- How can they encourage wider market participation and new business models such as demand aggregation and regional markets?

The energy storage market is evolving at an alarming rate. The policy landscape, funding opportunities and technology developments will have a significant impact on how, when and where this change occurs.

[16] National Grid, 2017 http://www2.nationalgrid.com/UK/Services/Balancing-services/Future-of-balancing-services/

3.1 Policy landscape

This change, primarily the decarbonisation of the energy system, is driven by UK policy:

- **Climate Change Act (2008)** - reducing greenhouse gas emissions by at least 80% of 1990 levels by 2050. A number of carbon budgets are now set in UK legislation. The government is confident that they will meet the 3rd (2018-2022) carbon budget, but are predicting that they will not meet the 4th (2023-2027) and 5th (2028-2032) carbon budgets - by a significant margin[17].

- **Paris agreement** (COP 21)[18] – the UK has ratified an international commitment to limit the rise in global temperatures to less than 2°C and pursue efforts to limit it to 1.5°C. This commitment was specifically mentioned in the Queens speech in June 2017.[19]

In addition, the UK adopted the EU Renewable Energy Directive 2009[20], which legally binds the UK to source 15% of all energy and 10% of transport fuels from renewables by 2020. A recent parliamentary inquiry stated that, 'on its current course, the UK will fail to achieve its 2020 renewable energy targets'[21]. However, Brexit may have some impact on this specific policy pressure.

Overall, we need to decarbonise our energy system, including generation, heat and transport. This needs to occur rapidly - over the next few years/decades – and we have some strong UK policy drivers to do so.

There have been a number of recent policy announcements specific to energy storage (see Table 2). Many of them have been positive - most notably the recent smart systems and flexibility plan from BEIS and Ofgem[22] - but crucially, not all. The most significant negative change is the de-rating of energy storage in the Capacity Market. This change was a distinct departure to previous policy announcements that had been made a couple of months previously and shows the additional risk involved in such a rapidly evolving and uncertain market.

In general, the direction of travel in the energy storage policy landscape is beneficial. There have been some notable bumps in the road, but there seems to be a consistent intent from government and the regulator to make changes that help rather than hinder the market. Regen and others will continue to make sure they deliver on their promises and hold them to account.

https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2016

[18] Paris Agreement 2015 https://ec.europa.eu/clima/policies/international/negotiations/paris_en

[19] Queens speech 2017 https://www.gov.uk/government/speeches/queens-speech-2017

[20] EU Renewable Energy Directive 2009 https://ec.europa.eu/energy/en/topics/renewable-energy/renewable-energy-directive

[21] 2020 renewable heat and transport inquiry http://www.parliament.uk/business/committees/committees-a-z/commons-select/energy-and-climate-change-committee/inquiries/parliament-2015/heat-transport-15-16/

[22] BEIS/Ofgem, 2017 https://www.ofgem.gov.uk/system/files/docs/2017/07/ssf_plan_-_summaries-responses.pdf

Table 2: Overview of recent policy changes and the impact on energy storage

Recent policy and regulatory developments	Potential impact on energy storage
BEIS and Ofgem – Smart systems and flexibility plan (Full details here)	Positive – the plan shows that both government and regulator are looking for ways to encourage greater flexibility in the UK energy system. Key points: • £246 million of funding through Faraday challenge • New licence condition for energy storage as subset of generation • Forcing Distribution Network Operators (DNOs) to do more to enable energy storage to connect to the network and statement that they should not own energy storage in most instances • Removal of barriers for independent aggregators.
Consultation on de-rating of storage within capacity market (Full details here)	**Negative –** this change could have a significant impact on energy storage projects committed to the Capacity Market, by slashing the income associated with their contracts (by up to £10k/MW/yr). The change was tabled by two established energy companies and impacts the majority of energy storage projects (Lithium-Ion batteries), which have been designed to provide 30 minute to 1 hour discharge duration. The argument for the change is that a 'stress event', where the capacity market projects are contracted to discharge, could last longer than an hour – at which point the storage would not be able to provide energy. Those projects that have longer duration will get a higher rate (%) for their service.
Reducing the level of peak Red Band peak charging in favour of higher off-peak charges (modification to the Common Distribution Charging Methodology - CDP228)	Somewhat negative – the change to the way distribution network charges are calculated will vary across licence areas but the general direction has been to reduce the highest red band changes with an increase in green and amber (off peak) charges. The effect for energy storage is to reduce the relative value of discharging during peak time periods. This reduces the business case for distribution connected energy storage.

Changes to "embedded benefits" (a lower set of network charges and exemptions for generation less than 100 MW capacity) (Full details here)	**Negative** – although the measure is intended to discourage diesel and gas reciprocating generators it will have a direct impact on energy storage revenue streams removing a potential £45 per kW revenue stream which was expected to grow as Triad based transmission costs increase over time. Although this decision was widely publicised last year, the decision and the governance process by which the decision was reached, has had a negative impact for storage investors. It could even mean that some of those projects that successfully bid into the 2016 Enhanced Frequency Response and Capacity Market may not now go ahead.
Removal of "double charging" of grid and network charges by treating storage, for the purpose of charging, as generation.	**Positive** - if implemented this would be positive and would remove a source of additional network costs for energy storage providers.
Ofgem's announcement of a targeted charging review, May 2017	**Positive** – the industry has been calling for a more holistic review of network charging although it is unclear whether this review will in fact look at all aspects of the charging regime and whether it will also deal with the governance and transparency issues which will continue to hamper future investment.
Distribution Network Operator (DNO) to Distribution Systems Operator (DSO) transition	**Positive** – the process of transition continues but it is not yet clear what the future model will be. In general, DSO's will procure a wider range of flexibility services locally, including energy storage. This will open up more markets for energy storage projects to access. UK Power Networks and Scottish and Southern Electricity Networks (SSEN) have already announced plans to tender for flexible capacity at certain substations, as an alternative to upgrading the network infrastructure.
Elective half-hourly settlement for domestic and small commercial allowing more variable time of use tariffs (Full details here)	**Positive -** the introduction of elective half-hourly settlement (June 2017) paves the way for more variable time of use tariffs, improving the benefits of energy storage for the small commercial and domestic markets. To grow the market further half-hourly settlement needs to become mandatory. A decision on the timetable for this is expected early 2018.
Brexit and the general election result	**Uncertain -** very hard to tell, but obviously the recent political uncertainty has had an impact on the market and has had a direct impact in terms of delays to policy decisions from government.

3.2 Funding opportunities

Energy storage is a new market and as a result requires further research and development in order to grow. The most significant recent announcement has been the £246 million Faraday challenge in July 2017[23], which is seen as a 'key part of the Industrial Strategy' from the government.

There are a number of opportunities for businesses to get involved at a variety of scales. SME's are likely to be involved in a supporting role behind a lead partner in most cases. However, it is still worth being aware of the variety of the funding available (Table 3).

Figure 9: Graphic from government on launch of the £246 million Faraday challenge. Source: BEIS

[23] BEIS, 2017 https://www.gov.uk/government/news/business-secretary-to-establish-uk-as-world-leader-in-battery-technology-as-part-of-modern-industrial-strategy

Table 3: A table of the main funding opportunities for energy storage in the UK

Name	Funding source	Important dates	Scope	Amount available	Eligibility/Restrictions
Open Programme Round 3 (R & D) Details here.	Innovate UK	Competition runs from: 12/06/17 – 09/08/17	The project must demonstrate game changing innovation that will lead to new products, processes or services. It should also show potential to have a commercial impact and significant return on investment. The project should last between 6 and 36 months.	Total eligible project costs should range from £25,000 to £1 million. There is up to £15 million allocated to fund innovation projects in this competition.	The competition is open to UK based businesses only. Priority is given to those who can make sustainable gains and access new overseas markets through export led business growth. Projects can focus on: • feasibility studies Industrial research • experimental development.
Faraday Challenge: Scale up – National Battery Manufacturing Development Facility Details here.	BEIS/APC	Competition runs from: 25/07/17 – 14/09/17	The bid will design, create and operate a single battery facility in the UK. This must be open by late 2019/early 2020.	As this is an industrial scale facility, anticipated project costs are in the region of £40 million.	The competition is open to UK based businesses only. The competition does not fund projects that are covering: • manufacture and development of Battery Manufacturing System hardware/software • installation of battery packs in vehicles.
Faraday Challenge: Innovation – research and development Details here	BEIS/ Innovate UK	Competition runs from: 25/07/17 – 14/09/17	In line with the objectives of the Faraday Challenge, we are looking to fund projects that address the following technical and supply chain challenges: cost, energy density, power density, safety, temperature, predictability, recyclability, cell and pack production, and a battery as a system. Up to £30 million available	Projects should range in size from total eligible costs of £1 million to £15 million.	To be eligible you must: • be a UK-based business or research and technology organisation working within the limits provided in the general guidance for applicants • carry out your project work, and intend to exploit the results, in the UK • work in collaboration with other grant claiming partners (businesses, research organisations and/or third sector).

Faraday Challenge: Innovation – feasibility studies Details here.	BEIS/ Innovate UK	Competition runs from: 25/07/17 – 14/09/17	UK businesses can apply for a share of up to £10 million to work on innovation projects to design, develop and manufacture batteries for the electrification of vehicles.	Projects should range in size from total eligible costs of £150,000 to £1 million. Up to £10 million available.	To be eligible you must: • be a UK-based business or research and technology organisation working within the limits provided in the general guidance for applicants • carry out your project work, and intend to exploit the results, in the UK • work in collaboration with other grant claiming partners (businesses, research organisations and/or third sector)
Infrastructure Systems Round 3 Details here.	Innovate UK	Competition runs from: 10/07/17 – 13/09/17	The project must develop innovative solutions to challenges in infrastructure systems. The project should last between 3 months and 3 years.	Total eligible project costs should range from £25,000 to £5 million. There is up to £15 million allocated to fund innovation projects in this competition.	The competition is open to UK based businesses only. Proposals must improve business growth, productivity and/or create export opportunities for at least one UK SME involved in the project. To lead a project, must either be an SME or work in collaboration with at least one SME.
APC8: Anchoring Low Carbon Technology in the UK (R&D) Details here.	APC	Competition runs from: 10/07/17 – 20/09/17	The aim of the competition is to address the challenges associated with: • producing lower carbon transportation • improving air quality • developing a UK supply chain for the next generation of lightweight vehicles and propulsion systems. Therefore, energy storage and energy management is one of the projects that Innovate UK are aiming to develop through this funding.	Total eligible costs of between £5 million and £40 million. There is up to £35 million allocated to develop low carbon technologies in this competition.	The competition is open to UK based businesses only. Projects need to be collaborative and business led, with a clear route to market. The project must involve at least one vehicle manufacturer/tier 1 supplier and at least one SME.
Electricity Network Innovation Competition Details here.	Ofgem	Annual opportunity	For electricity network companies to compete for funding for the development and demonstration of innovative technologies, operating and commercial arrangements.	Up to £70 million per year is available.	Funding is provided for the best innovation projects which will aid all network operators in understanding future environmental benefits, cost reductions and security of supply in the transition to a low carbon economy.

Horizon 2020 Details here.	European Commission	Funding available from 2014 – 2020	The Energy Challenge is structured around seven specific objectives and research areas: • reducing energy consumption and carbon footprint • low-cost, low-carbon electricity supply • alternative fuels and mobile energy sources • a single, smart European electricity grid • new knowledge and technologies • robust decision making and public engagement • market uptake of energy and ICT innovation.	Provides €5.931 billion in funding towards energy projects.	The funding is for projects that establish or explore the feasibility of new knowledge or technology. There are several 'streams' available, including: • innovative actions • coordination and support actions • SME instrument • fast track to innovation.
INTERREG V Details here.	European Commission	2014 – 2020	The overall budget is €10.1 billion. The average total budget for a project is €1 – 2 million.	The EU provides approximately €9 billion for the European Territorial Cooperation from 2014: €6.6 billion for the cross-border cooperation (INTERREG VA), €1.8 billion for the transnational cooperation (INTERREG VB) and €500 million for the inter-regional cooperation (INTERREG VC). Interreg V co – finances up to 85% of project activities.	This is part of the European Regional Development Fund which has a specific focus on sustainable development with the aim of strengthening economic and social cohesion in the EU. It supports interregional cooperation projects. These projects involve policy organisations from at least three different countries in Europe and collaborate for 3 – 5 years.
EUREKA Eurostars Details here.	Innovate UK	Two calls for proposals each year between 2014 and 2020.	This is specifically for SMEs that wish to take part in collaborative research. The programme supports the development of new products, processes or services. Applications can be with 2 or more participants from 2 or more Eurostars countries.	Up to 60% of eligible project costs are accounted for –a maximum of €360,000 is available per UK project partner.	Exclusively for innovative intensive and research performing SMEs are eligible for funding in the UK.

3.3 Technology developments

Cost reduction

One of the main reasons for the rise in interest for energy storage is the significant cost reduction seen over recent years. This has been due to the proliferation of the Electric Vehicle (EV) market and the associated increase in Lithium-Ion battery cell production. The high level of cost reduction for battery units is likely, assuming global market growth and continued scaling up of manufacturing capacity.

In general, the energy storage technologies that are most mature have the biggest cost reduction potential - mainly Lithium-Ion batteries at this stage (see right). Other technologies and battery types are likely to compete moving forward, particularly in bulk or longer duration energy storage applications.

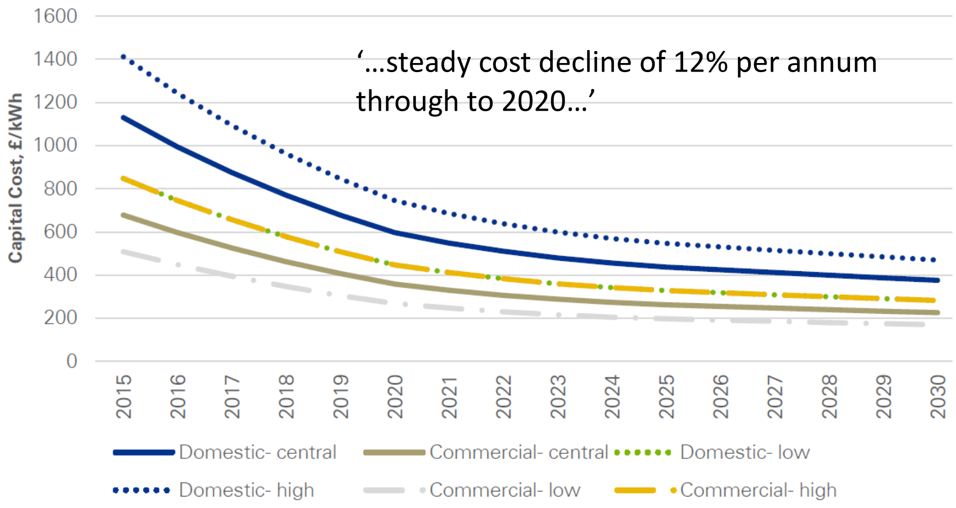
The impact on the business case for individual energy storage projects will be more complex. The full system cost of individual projects will depend on a wide range of factors and the specific services targeted.

Hybrid technology systems

A recent development in the market is the introduction of hybrid technology systems that take complementary characteristics of different technologies to provide an optimal solution (see Highview Power on page 9).

The expected advantages are lower cost, increased system efficiency, and increased system lifetime due to optimised operation and the ability for hybrids to do more and last longer with less overall storage capacity. These projects are currently at the demonstration stage, but could become significant over the next few years.

Cost reduction predictions for Lithium-Ion energy storage



‘20% reduction in 2016…15-20% predicted for 2017’

Bloomberg NEW ENERGY FINANCE

KPMG, 2016 https://assets.kpmg.com/content/dam/kpmg/pdf/2016/05/rea-storage-report-may-2016.pdf
BNEF, 2016 https://www.bloomberg.com/company/new-energy-outlook/

Aggregation

Aggregators combine and control flexible electricity demand and generation, then sell that service to system operators, to help them balance the network. The systems are a key form of innovation in the industry and provide potential income streams to those energy storage projects that cannot access the complex national contracts directly. The UK is leading the development and application of aggregation platforms in many areas. There is a well-documented success story, with Moixa and Upside Energy notable examples resident in the Manchester area (see page 32 and 33).

When you combine aggregation with energy supply opportunities for consumers, you can provide additional benefits to consumers. This model is yet to come to the UK, but could become influential in the near future (see right).

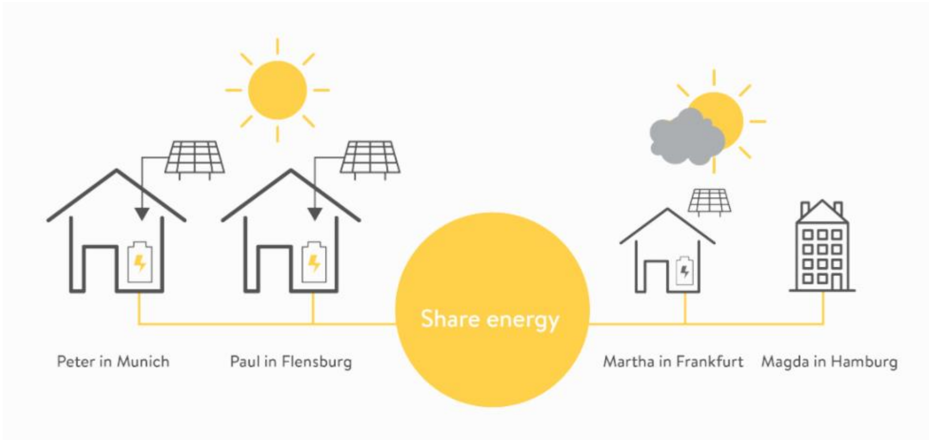
Figure 10: A graphic of the aggregator companies used by National Grid. The green circle shows the larger energy supply companies active in the market.

sonnen community

This is an offer for German consumers initially (primarily for those with solar PV and sonnen batteries). The key points are below:

- The sonnen community become your energy supplier
- For a membership fee of €19.99 per month, you can share the electricity you produce with others in the community and get paid a better rate than you would for simply exporting to the network. You then get a preferential rate on any additional electricity you need to import.
- Reduced price sonnen battery.

This offer is due to come to the UK soon (2017/2018).



www.sonnenbatterie.de/en/sonnenCommunity

4. The current state of the energy storage market

The energy storage market is diverse and evolving quickly. The main categories we use to characterise the market are the domestic (0-30 kWh), commercial (30kWh to 1 MWh) and grid-scale (1 MWh +) energy storage. These categories are approximate and will depend on the project in question.

In this section, we summarise some of the consumers, companies that are active and potential commercial models available. Please note these models are simplified and there may be variations that can be applied. For more detail on these models refer to the Regen document, Energy storage – Towards a commercial model (2nd edition)[24].

4.1 Domestic energy storage

The domestic energy storage market is at a relatively early stage of development. There is no deployment data available, but including the quantity of innovation projects and trials, the number of installations in the UK is likely to be in the low thousands, the vast majority of which are battery installations (normally associated with solar PV).

Consumer profile

The consumers at this scale are motivated by:

- wanting to go "off-grid" and back-up capability in a power cut
- increasing their own-use of the electricity from their solar PV
- being green "eco chic" gadget lovers.

The products currently available (see Figure 11 for list of some manufacturers) provide varying degrees of these outcomes. Many products do not provide back-up capability. In addition, it can be uneconomic to size a battery for you to go to "off grid" for a significant period of time. This difference between customer expectation and the outcomes that are viable should be explained upfront. The recent release of the Institute of Engineering and Technology (IET) Code of practice for Electrical Energy Storage Systems[25], should help improve standards and consistency in the sector.

Figure 11: A graphic of some of the active manufacturers in the domestic energy storage market

[24] Regen, 2016 https://www.regensw.co.uk/storage-towards-a-commercial-model

[25] IET, 2017 http://www.theiet.org/resources/standards/eess-cop.cfm

Income streams

The income streams associated with a domestic energy storage market are limited. There is no subsidy type support mechanism. In other European countries, such as Sweden and Germany, there is grant available. There are no plans to do so in the UK.

Generator 'own use' - the electricity storage installation will increase the 'own use' of the electricity generated by microgeneration (mainly solar PV panels), which means less is imported from the network, saving the costs associated. This is shown in Figure 12 as the dark blue section of the bar graph.

Price arbitrage/peak shaving - one of the main price/ time shift services that can be provided by energy storage is price arbitrage – using a storage device to import energy at a low price and export it back to the network at a higher price. This is related to peak shaving, where the high costs of electricity at peaks periods are avoided by using energy from electricity storage at those times. These revenue streams are currently only available at the non-domestic scale. With the introduction of smart meters across the UK (due to be offered to all households by 2020), more variable time of use tariffs[26] for our electricity will follow and allow the benefits of price arbitrage and peak shaving to be passed on to domestic consumers. This income stream is shown as light blue in Figure 12.

Aggregator payment - the grouping together, or aggregation, of energy storage with local generation, provides an opportunity to unlock more revenue streams and make best use of energy storage. This requires communication and control systems to be fitted to the energy storage devices and a platform to collate the different installations together. Aggregators already pay energy storage owners for use of their devices at certain times. For example, in the UK, the Moixa Gridshare offers £50-£75 per annum for the ability to utilise installed batteries. This is shown as grey and black section of the bar graph in Figure 12. There are other aggregators that could start offering payments to domestic storage (Figure 10).

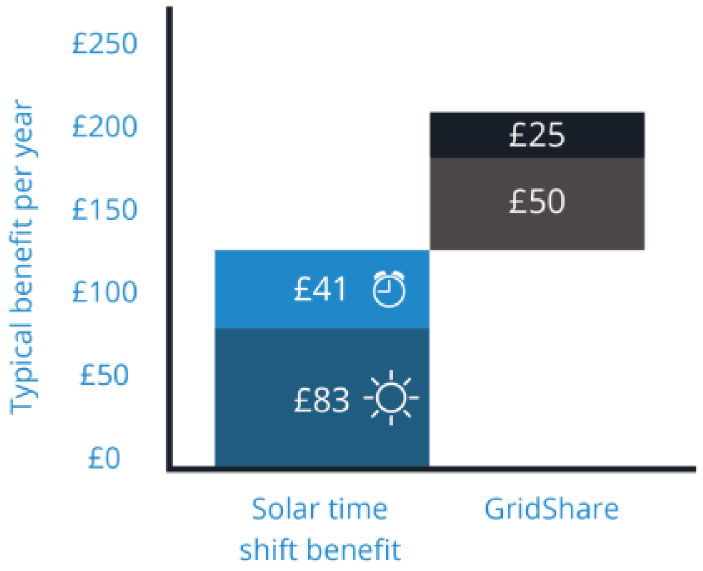


Figure 12: Proposed income streams for domestic energy storage (Source: www.moixa.com/products/)

[26] Time of use tariffs – a variable tariff per unit (p/kWh) depending on the time of day. The introduction of smart meters allows for more variable pricing for our electricity. Economy 7 (and 10) tariffs are the main time of use tariffs currently available and offer a peak and off-peak tariff rate.

4.2 Commercial and grid scale energy storage

The domestic electricity storage market is steadily growing. The markets for larger scale electricity storage installations are more mature and some of the revenue streams have been operational for some time.

Consumer profile

Commercial consumers in the energy storage market are likely to be large users of energy and/or those that require an alternative back up electricity supply in a power cut. The main driver is the reduction in peak network costs, by using energy storage to supply electricity at these times. They are looking to make a return on their investment and are interested in lease/finance models to reduce

Grid scale energy storage providers are not consumers in the marketplace, but are developing projects in order to deliver services to the network – normally National Grid (Figure 14).

Response service

They are normally rapid (sub-second to seconds) and delivered over a short time frame (5 to 30 mins) to maintain the frequency of 50 Hz on the network. The 200 MW Enhanced Frequency Response service[27], tendered by National Grid, is one example of this service. This is likely to be provided by a large electricity storage installation (10-20 MW power rating and 6-10 MWh energy capacity), situated on a brownfield site (e.g. an industrial estate) with good network capacity available.

In addition, this model can access the capacity market[28] in certain situations. The response service model has seen considerable commercial interest and has been the main driver for large energy storage projects so far (See Figure 16 for a map of Greater Manchester sites).

Figure 13: A graphic of some of the active manufacturers and companies in the commercial and larger scale energy storage market

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[27] National Grid, 2017 http://www2.nationalgrid.com/Enhanced-Frequency-Response.aspx

[28] National Grid, 2017 https://www.emrdeliverybody.com/cm/home.aspx

High energy user 'behind the meter'

A 'behind the meter' electricity storage installation refers to a project on the consumer side of the electricity meter. In this case this would be located with a high energy user, such as industrial manufacturers, data centres or hospitals. This model is based on using electricity storage to avoid higher energy consumption costs at peak periods. The addition or integration of other on-site generation can help enhance this model. As mentioned in the domestic models for electricity storage price arbitrage and peak shaving are potential revenues for electricity storage, which can be more significant at the non-domestic scale (particularly those with a network connection more than 100 kW).

Reducing network costs - the cost of the network is charged to generators and demand users. The half-hourly charges for these payments is complex, but the charges are particularly high during times of peak demand on the network. Energy storage projects can be used to avoid these times of peak demand and assist the network by exporting/importing energy during these times (gaining a revenue in some instances). This revenue stream is not fixed and varies depending on the location and at what level you connect to the network. Recent changes have been announced and there are due to be more following the consultation.

Generator network restriction - when new renewable generation (such as solar PV) is located with a high energy user, other revenues can become important. If an installation cannot discharge to the network or has a limitation of some sort in their grid connection, then energy storage can be used to store this energy. Electricity North West do not currently offer flexible connection types[29] that often have these restrictions, but this could change in the near future.

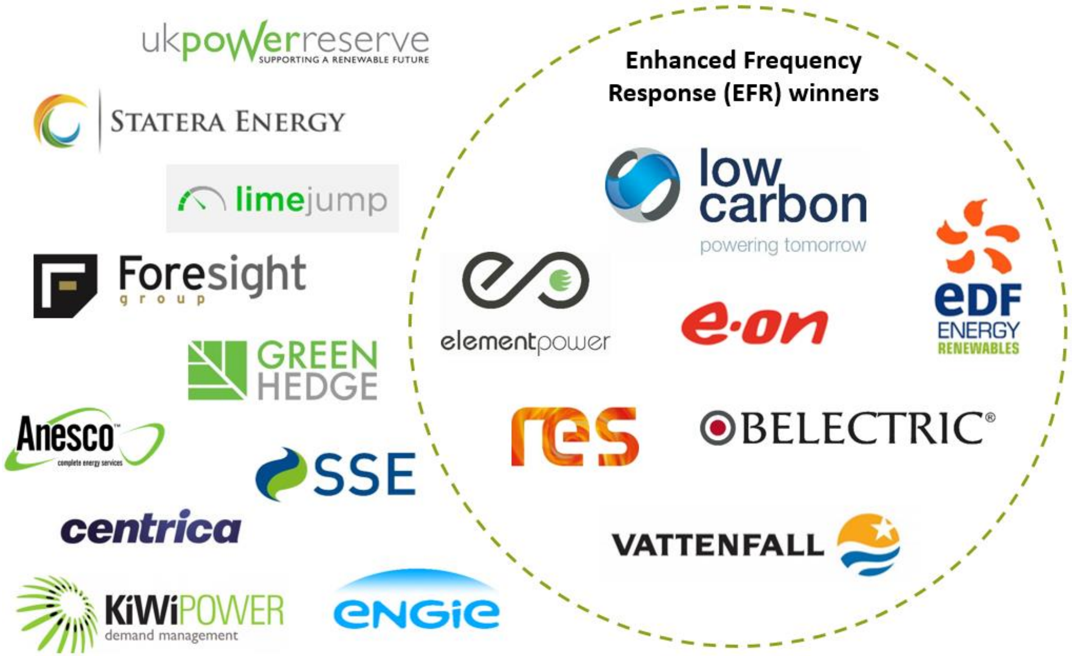


Figure 14: A graphic showing the main grid scale energy storage companies that have been successful in winning contracts with National Grid

[29] ENA, 2016 http://www.energynetworks.org/electricity/futures/flexible-connections.html

4.3 Greater Manchester market structure

In discussing the progress of energy storage in the Greater Manchester area, we chose to limit our analysis to a specific 'study area' (See extent of map in Figure 16). This was to take into account the opportunities for SME's in the area surrounding the Greater Manchester and to define a boundary for mapping activities.

Large storage developments in the study area

The Manchester area is well placed to take advantage of the large energy storage project market. This is due to an availability of good connections to the electricity network and relatively cheap industrial land (Figure 16). This is shown by the high number (12) of bids to the Capacity Market (CM) and to a lesser degree Enhanced Frequency Response (Figure 15).

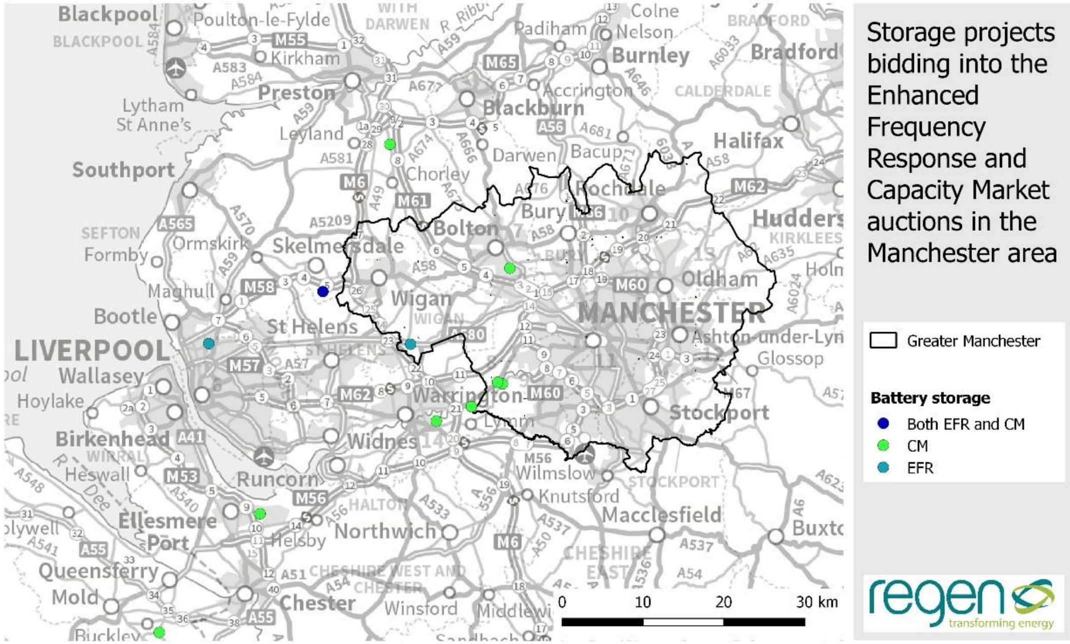


Figure 15: A map of large scale energy storage projects bidding into the Enhanced Frequency Response (EFR) and Capacity Market (CM) auctions in study area

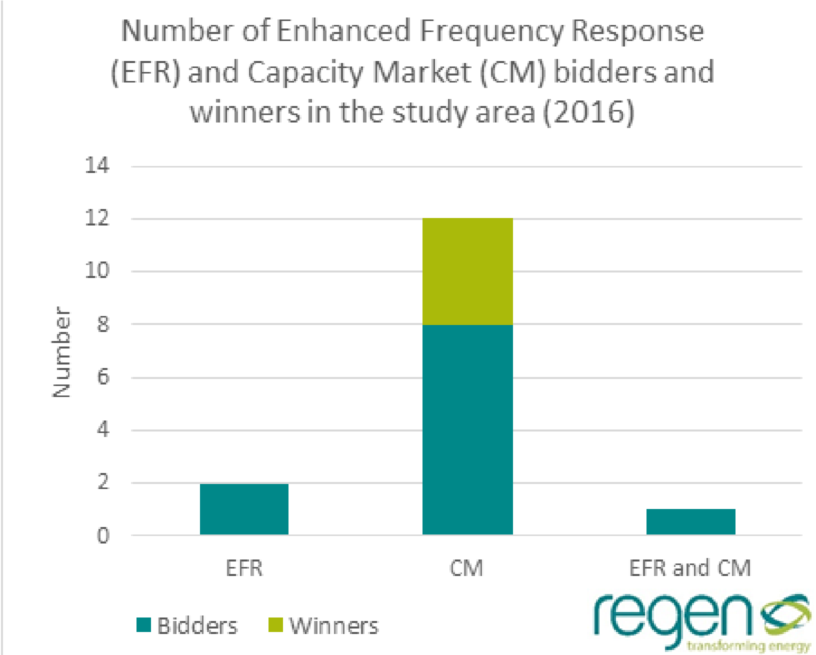


Figure 16: Graph of the number of large scale energy storage in the study

A more detailed look at the winning large energy storage projects

Of those that bid, only four won CM contracts in the study area. All of these projects are to be developed by UK Power Reserve (UK Energy Reserve Ltd.)[30]. UK Power Reserve is the UK's second largest developer of battery storage projects, having been awarded a total 120 MW of battery storage in the 2016 Capacity Market Auction. The construction of this pipeline of projects is set to begin this year.

The four winning projects in the study area (two of which fall within the Greater Manchester area) are all new builds to be commissioned before 2020, with a Capacity Market contract length of 15 years each. The proposed capacity of 9.629 MW at each site will be met by multiple Lithium-Ion battery units, normally housed in shipping containers.

The sites chosen for these developments are all in industrial areas located close to electricity network substations (three out of the four are within 7 km of their nearest substation). For example, a storage project in Farnworth, Bolton will be located approximately 6 km from the nearest substation and a development on Manchester Road, Carrington will similarly be less than 3 km from the nearest substation in a heavily industrialised area.

Table 4: List of large energy storage developments in the study area

Location	Technology	Capacity	Capacity Market contract length	Land classification	Proximity to substation
Oil sites Rd, Ellesmere Port	Lithium-ion	9.629 MW	15 years	Industrial	c. 6 km
Thelwall Lane, Warrington	Lithium-ion	9.629 MW	15 years	Industrial	c. 16 km
Manchester Rd, Carrington	Lithium-ion	9.629 MW	15 years	Industrial	c. 2.5 km
Emlyn Street, Farnworth	Lithium-ion	9.629 MW	15 years	Industrial	c. 6 km

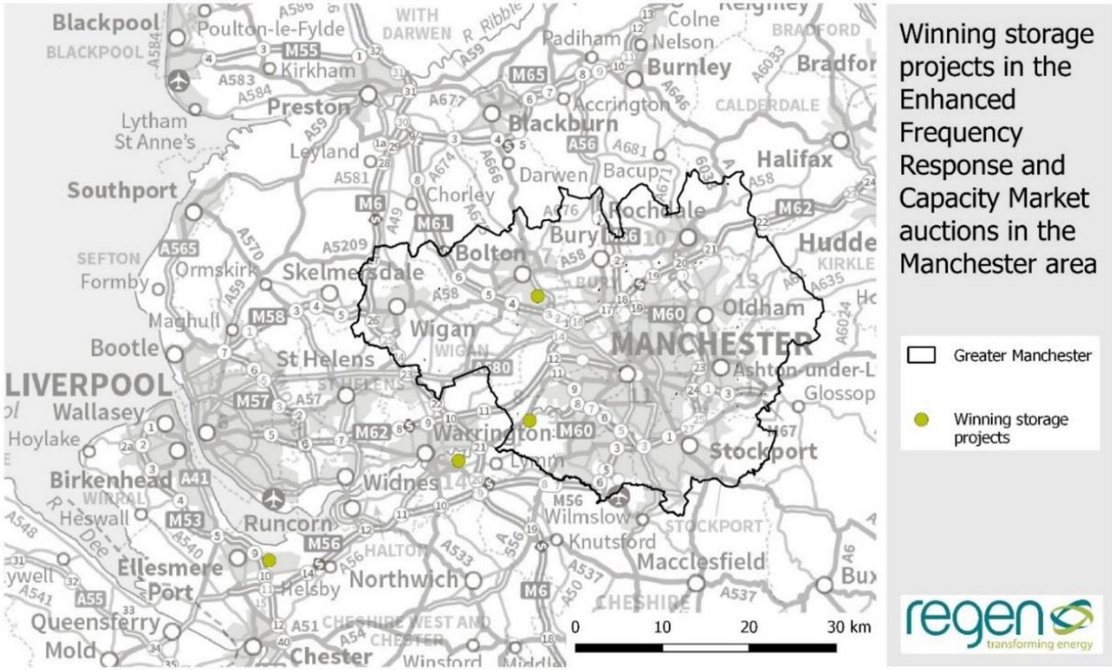


Figure 17: Map of four large energy storage projects in the Manchester study area that won a capacity market contract

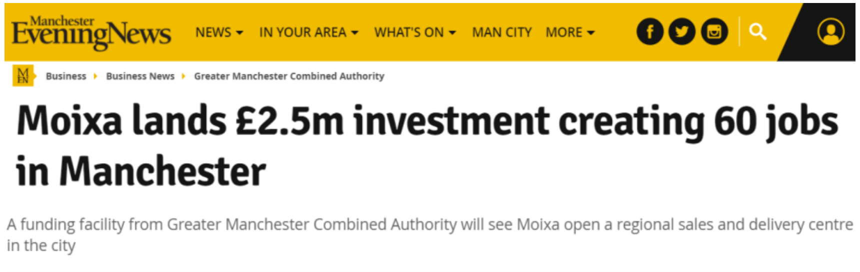
[30] UK Power Reserve, 2017 https://ukpowerreserve.com/

Other examples of energy storage projects in the Manchester study area

One of the most publicised examples of energy storage promotion has been the partnership of Eaton and Manchester City FC (see right). This has the potential to reach a base of customers that would otherwise not have thought of purchasing an energy storage product. Eaton are still looking for local installer partners - a clear opportunity for SME's in the Manchester area.

Another key announcement in June 2017 was from Moixa, one of the leading UK storage companies (see below). They have stated that they are opening a regional sales and delivery office in Manchester with 20 full time staff (rising to 60). This was following £1 million of funding from the Greater Manchester Authority – a significant endorsement of the sector.

Case study - Moixa in Manchester


Manchester Evening News NEWS IN YOUR AREA WHAT'S ON MAN CITY MORE

Business › Business News › Greater Manchester Combined Authority

Moixa lands £2.5m investment creating 60 jobs in Manchester

A funding facility from Greater Manchester Combined Authority will see Moixa open a regional sales and delivery centre in the city

www.manchestereveningnews.co.uk/business/business-news/moixa-home-batteries-investment-manchester--13244603

www.moixa.com/

Case study - Eaton and Manchester City FC partnership

Eaton are an international power management company, headquartered in the US, involved in network communications, electricity transmission and energy storage. The UK headquarters is based in Manchester.

Eaton and Manchester City FC have partnered in a marketing campaign to increase the awareness of energy storage and to deploy sustainable energy usage at the Etihad Stadium and City Football Academy. This kind of marketing approach is rare in the energy storage market and the impacts of it will be interesting to see.

Of particular note is the use of the branded Nissan xStorage product (see below) and the integration of second-life batteries from Nissan Leaf Electric Vehicles (EV's), built in Sunderland. A great example of a UK produced and manufactured energy storage product offer.

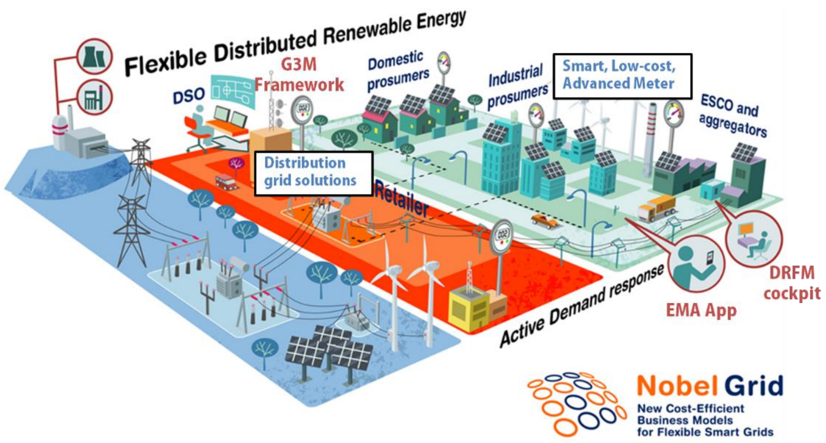
uk.eaton.com/content/content-beacon/manchester/end-user/home.html

https://www.youtube.com/watch?v=yJ9UaIXuBUc

Case study - Carbon Co-op

Carbon Co-op is a group of Greater Manchester residents who have teamed up with housing specialists to improve the energy performance of members' homes through a variety of initiatives and schemes.

One scheme they are currently involved in is the €14 million EU-funded Horizon 2020 Nobel Grid trial, which will see between 100 and 200 households in Greater Manchester connect to a community smart grid. Working together they will save energy and reduce carbon emissions by utilising modern technologies such as smart meters and smart phone apps. More importantly, there is due to be up to five communal 10 kWh energy storage projects installed.



Carbon Co-op also run seminars, workshops and talks, which have recently included talks from masters students studying energy storage and a workshop building smart energy dashboards.

There are potential opportunities for SMEs to provide advice, install smart grid infrastructure including smart meters and batteries, and to get involved through delivering or attending talks, seminars and workshops.

carbon.coop/

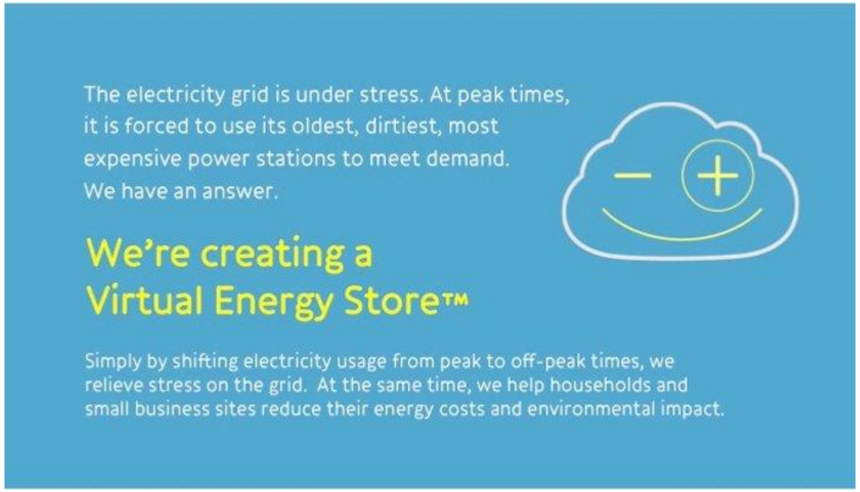
http://nobelgrid.eu/

Case study - Upside Energy

Upside Energy is a start-up based in Salford that have developed a cloud-based Virtual Power Plant (VPP) service, called the Virtual Power Store™. A VPP is a pool of small-scale generators and businesses with flexible demand that are aggregated and dispatched in response to grid balancing and market price signals, simulating a traditional power plant.

They aim to have 515 MW of capacity under management in the UK by 2025, including EV's, energy storage, solar PV and domestic electric heating, eliminating more than 300,000 tonnes of CO_2e.

Funding has mainly been through grants, including the Department for Energy and Climate Change's (DECC's) Energy Entrepreneurs Fund and a grant from Innovate UK to pilot the system and undertake a feasibility study of the potential to integrate domestic hot water systems into the service.



upsideenergy.co.uk/

Overview of businesses involved in energy storage in the study area

Through the use of our existing smart energy and storage company directory[31] and the data provided by the Business Growth Hub, we have identified 68 companies in the study area, 40 which are located in Greater Manchester (see Figure 16 and 17). A full list of these companies is provided separately.

Most of the businesses are involved directly with the installation of energy storage in some way (43%), mainly domestic systems. Many small microgeneration installers have diversified and used energy storage to help fill the hole of income from a reduction in demand for conventional solar PV systems. These companies often have standard electrical services offered at the same time with solar PV, LED lighting and energy storage products available. As the domestic energy storage market grows these companies are well placed to benefit.

Businesses involved in smart grid infrastructure are also evident (19%). These are mostly building or advising on the technology to be installed alongside energy storage for more flexible networks, such as metering, automation, and communications. The installation of energy storage can often require more complex metering/control systems, particularly at scale. In addition, detailed modelling of the power flows and the state of charge for an energy storage project should be carried, to size the system effectively. They will benefit as the networks evolve and energy storage markets mature.

Of the other key business types shown, demand side response and services and consultancy are crucial for the development of a smarter, more flexible network.

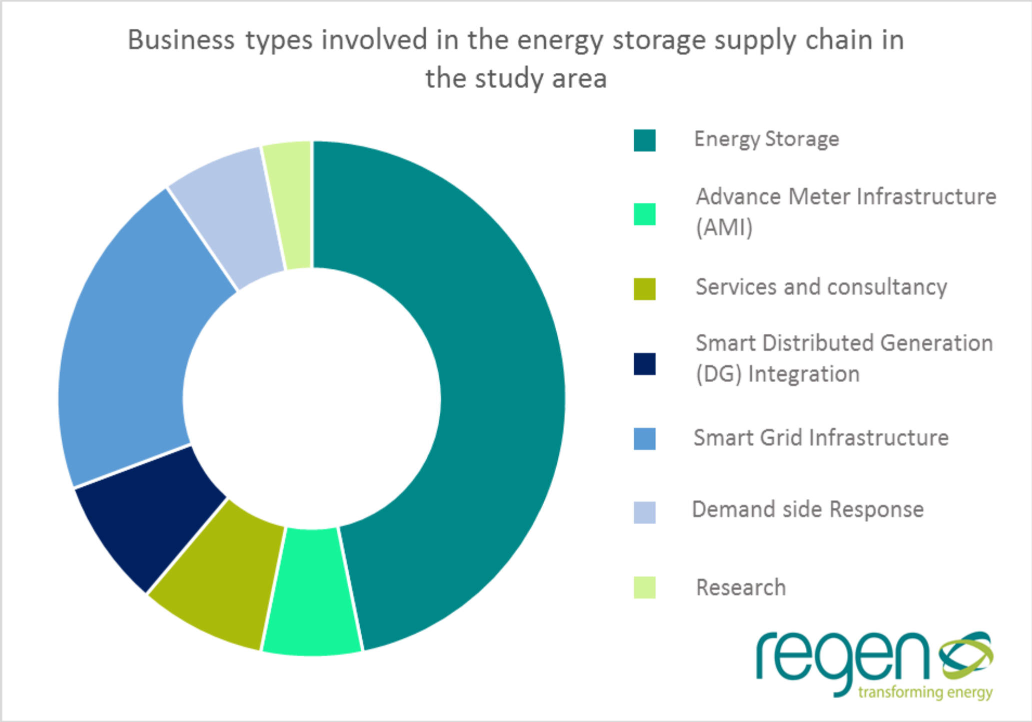


Figure 18: Pie chart of different business types involved in energy storage in the study area

[31] Regen, 2017 https://www.regensw.co.uk/smart-energy-and-storage-company-directory

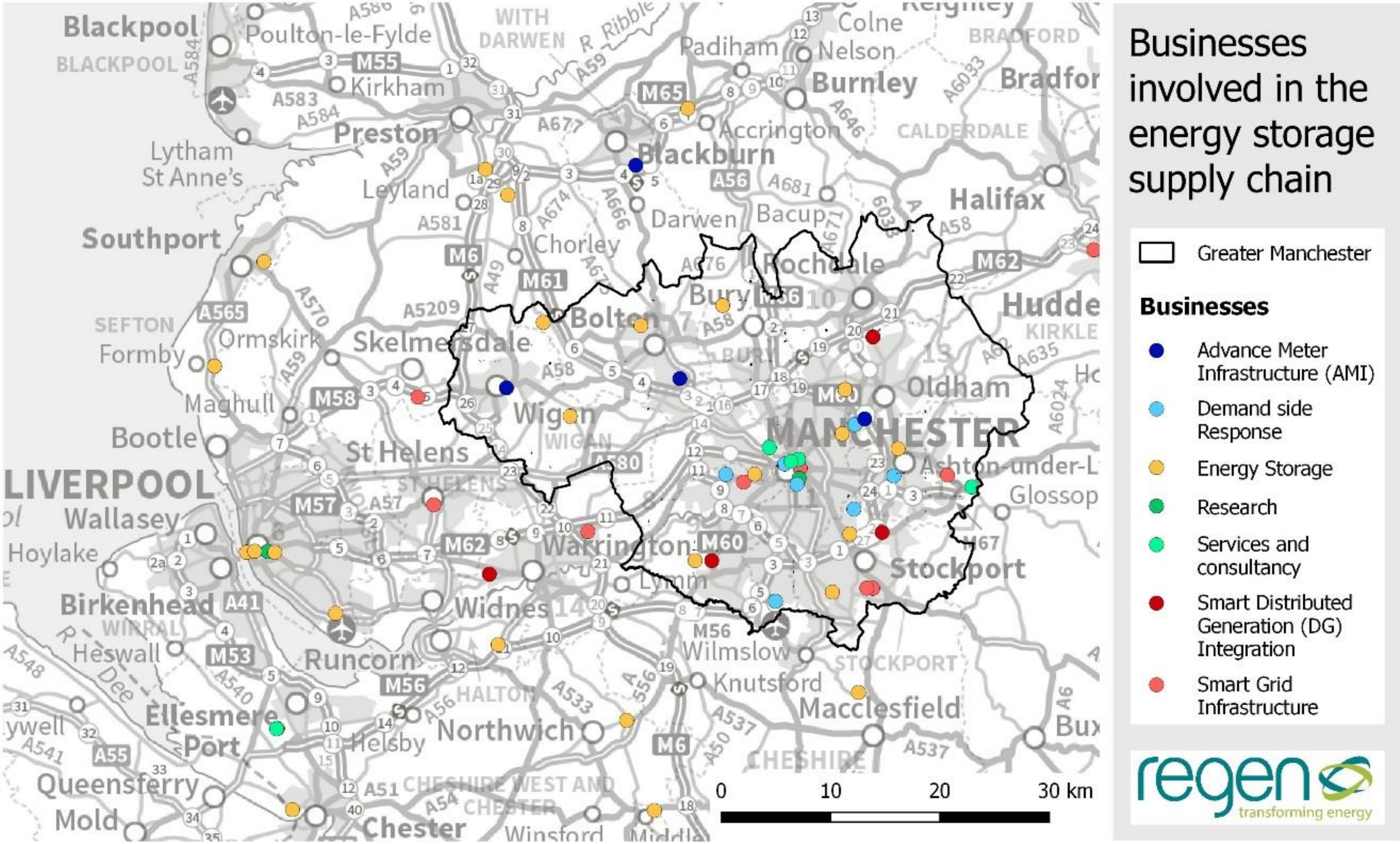


Figure 19: Map of all the businesses identified as being involved in energy storage in the study area

5. Energy storage growth forecasts

The 2016 Enhanced Frequency Response and Capacity Market auctions jump-started the electricity storage market development in the UK. All the DNO's, have received unprecedented interest in connecting storage assets. Industry analysts are predicting a very rapid growth in the energy storage market, with an early focus on battery storage for electricity.

National Grid Future Energy Scenarios

In addition to Regen predictions, National Grid produce their Future Energy Scenarios (FES) strategic document – the latest version of which was published on the 13th July 2017[32]. This document considers and discusses the role of energy storage in the future in 4 key energy scenarios – the approach that Regen used, with some small differences. In these scenarios, storage is referenced as a provider of flexibility, both for response and co-location with intermittent generation (both solar and wind) and highlights the expectation that energy storage will be a significant part of the ongoing energy transition towards a smarter and more distributed electricity system.

National Grid forecast strong growth in energy storage (in all scenarios) over the next few years, such that a total of 6 GW is forecast to be connected to the UK electricity system by 2020 (Figure 20). Beyond this, National Grid expectation for energy storage growth varies significantly across the scenarios proposed, with the highest two scenarios showing storage grow to 10 GW by 2050 (Consumer Power - 10.7 GW and Two Degrees - 9.8 GW). The considerably lower level of storage growth (under the Steady State scenario) shows 5.2 GW by 2050, due to low levels of available funding, coupled with a reduction in capacity from 2030 onwards, as a result of existing assets not being replaced when they reach end of life.

In general, this analysis agrees with the Regen forecasts outlined above, with strong growth in energy storage, particularly over the next few years up to 2020. The large range of values provided following this period is further evidence of the significant uncertainty in how the market is due to evolve.

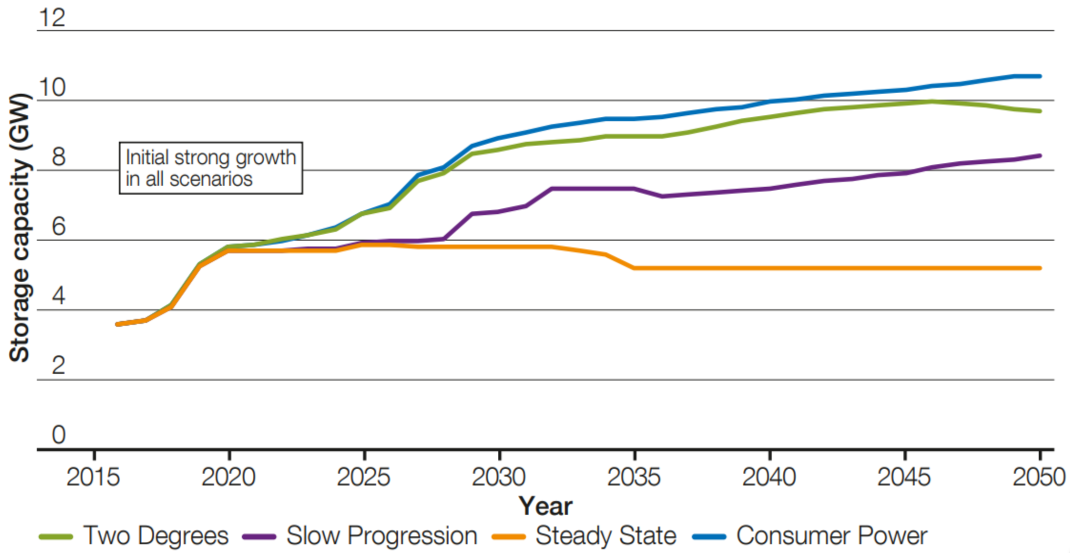


Figure 20: Energy storage capacity growth in National Grid future energy scenarios

[32] National Grid, 2017 http://fes.nationalgrid.com

5.1 Market segment growth forecasts

There are a number of different scenario-driven resources on the growth in energy storage. Regen have done some more work in assessing the extent of growth for different business models.

Regen energy storage growth scenarios

Regen has completed a series of studies looking at the potential growth of all generation and demand on the Western Power Distribution (WPD) and UK Power Networks (UKPN) regions. From this we have collated an estimate of how much energy storage is due to be installed across Great Britain (Table 5).

We have also collated a number of "waves of deployment" for energy storage (Figure 21). The first wave of connected storage assets appear to be focussing on frequency response, Capacity Market, Demand Side Response and potentially other grid and network services. In a high growth scenario, Regen's analysis anticipates that future waves of energy storage projects will target Commercial and Industrial (C&I) applications, domestic and small-scale energy storage and also co-location with generation and aggregation.

Table 5: Energy storage growth scenarios for the GB market

	GB market scenario growth scenario by 2030*		
Business model	**High Growth Scenario**	**Slower and no growth Scenario**	**Possible upside very high growth scenario**
Response service	2 GW 2 GWh	0.5 - 1 GW 0.5 - 1 GWh	2 - 3 GW 4 - 5 GWh
Reserve Services*	3-4 GW	2-3 GW	4 GW
C&I high energy user & behind the meter	2.5 - 4 GW 10 - 16 GWh	0.6 - 1.2 GW 2.5 - 5 GWh	5 GW 20 GWh
Domestic and community own use with PV* **	1.5 - 2 GW 6 - 8 GWh	0.37 - 0.75 GW 1.2 - 3 GWh	3 GW 12 GWh
Generation co-location	2 GW 6 - 8 GWh	0.5 - 1GW 2-4 GWh	4 GW 16 GWh
Total GB market	10 - 12 GW 24 - 44 GWh	4 - 5 GW 6 - 13 GWh	15 GW** 50 GWh

* includes existing 2.7 GW of storage – mainly pumped hydro reserve services
** A very high growth scenario for all business models would probably imply some degree of revenue cannibalisation between business models and is therefore less likely by 2030.
*** Would include EV vehicle-to-house storage discharge although this has not been modelled separately

Wave 1 - Led by response services (Now-2020)

- Focus on grid and network services (including frequency response & DSR)
- First applications for C&I 'behind the meter' models and co-location
- Domestic and community scale early adopters.

Wave 2 - Co-location business models become viable (Early 2020's)

- Market for C&I high energy users/generators grows rapidly
- Co-location projects with solar PV and wind become viable
- The domestic and community storage market expands.

Wave 3 – Market expansion and new business models (Mid/Late 2020's)

- Price arbitrage and new trading platforms develop
- Storage enables local supply markets, private wire and virtual markets
- Domestic electricity storage becomes common
- Most new solar and wind farms now include electricity storage to harness low marginal cost energy and price arbitrage
- Heat storage and electricity storage are increasingly integrated.

The overall storage deployment outcome for the higher growth Gone Green and Consumer Power scenarios are similar although the mix of storage assets deployed across business models is different.

A lower growth scenario could occur if, after the initial enthusiasm for electricity storage as a result of the Enhanced Frequency Response and Capacity Market auctions, future growth stalls. However, given the UK's legally binding commitment[33] to decarbonisation, and the fundamental need to increase energy flexibility, it seems increasing unlikely that a very low or no growth scenario for electricity storage is realistic.

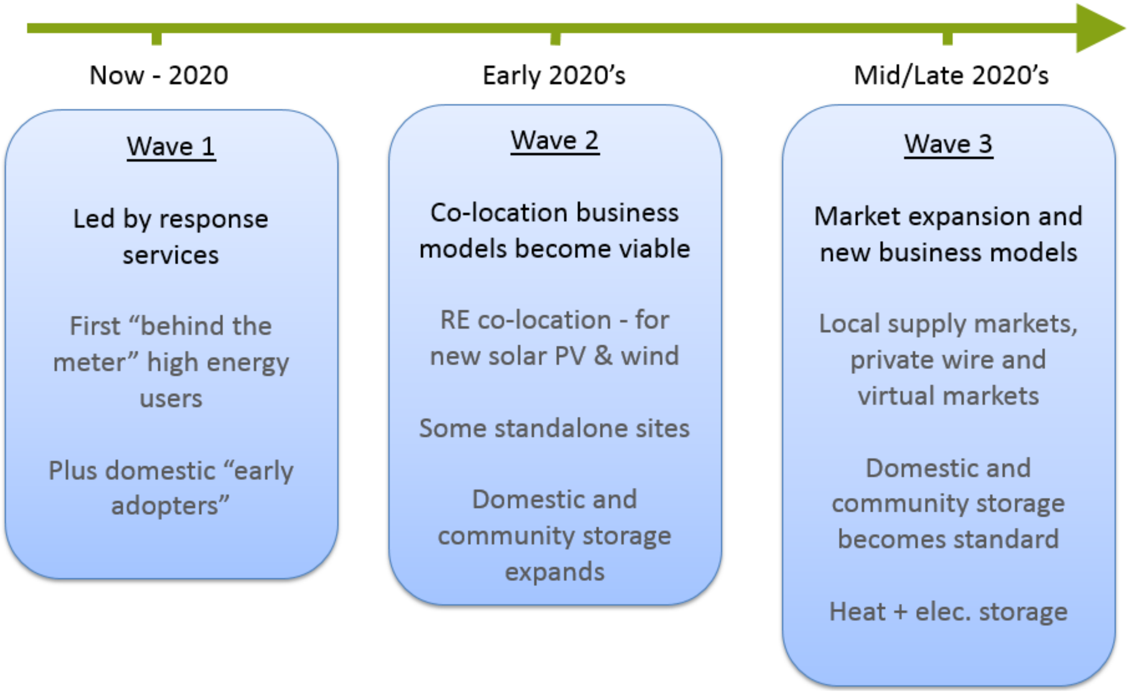


Figure 21: Graphic to show the potential waves of deployment for energy storage in the UK

[33] UK 5th Carbon Budget enacted July 2016

Western Power Distribution – energy storage consultation report

Associated to this energy scenario work, Regen has been working with one of the leading DNO's, Western Power Distribution (WPD), to assess the energy storage market[34]. This involved an industry consultation which has provided further detail on some key questions from a sample of 27 companies in the energy storage sector.

The key points from the analysis were:

- The vast majority of respondents agreed with the energy storage growth scenarios given - the Regen numbers outlined above (see Figure 22)
- Many respondents felt that some aspects of wave 2" of deployment are already happening
- Some respondents felt that from the current mix of energy storage technologies, flow batteries are primed for deployment growth in the next 2 to 5 years, with Compressed Air energy storage and supercapacitors becoming more viable after 5 years

To have good support for the Regen energy storage growth scenarios, from those active in the sector, shows that our thinking is leading the industry, at this time of rapid change. The evolving nature of the market was evidenced by the fact that many respondents already believed that some of the wave 2 deployment characteristics were already evident in the market. What remains to be seen is how DNO's can continue to integrate more intermittent renewable energy and energy storage, in a way that works for the sector, consumers and National Grid.

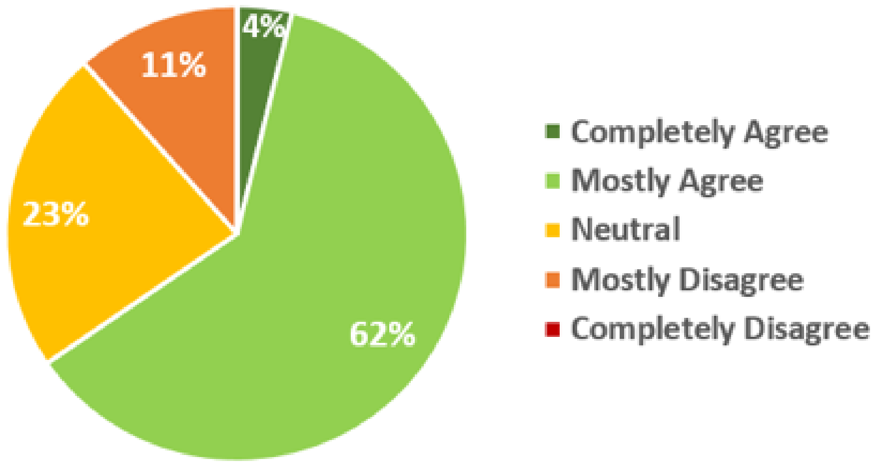


Figure 22: Overview of responses relating to the Western Power Distribution energy storage consultation report and the agreement with the Regen energy storage growth scenarios

[34] WPD, 2017 https://www.westernpower.co.uk/About-us/Our-Business/Our-network/Strategic-network-investment/Energy-Storage.aspx

5.2 Key inflection points for energy storage growth

As part of this analysis we thought it would be useful to analyse some key inflection points, which will mark key milestones in the energy storage growth projections:

1. What is to potential size of the Response Service market?

The purpose of frequency response is to maintain the 50 Hz frequency required for the networks to work efficiently. Fluctuations of frequency are getting more common due to the smaller number of large power stations, which help stop these changes, and more variable distributed generation. This means that the future requirements for frequency response will be linked to how the UK energy market evolves and the mix of generation types deployed. As mentioned earlier we are expecting a reduction in the number of large power stations and a growth in renewable energy with other forms of distributed generation. This means that more frequency regulation services will be required.

At present the frequency response services are run by National Grid using the Firm Frequency Response and Enhanced Frequency Response products. These services have been targeted by energy storage as they can offer an attractive revenue stream. However, competition in these markets has been fierce, with the 2016 Enhanced Frequency Response 200 MW auction showing much lower prices than anticipated (winning bids averaged. £9.44 per MW per hour rather than £40). Winners included some significant energy companies, looking to gain advantage by being an early innovator in the market, as well as other developers (see Figure 12).

It was expected that National Grid would release a further Enhanced Frequency Response tender in 2017, but these plans have been cancelled. The recent consultation, SNAPS from National Grid[35], mentioned that the frequency response products are likely to be combined under one service, due to be confirmed by March 2018. This would have different specifications and a trade-off - more rapid frequency response services, lowers the need for slower frequency response services. This is good for energy storage providers, as they are well placed to provide these services, and bad for the conventional power stations who currently provide much of the slower response services. The SNAPS document also discussed the need for more rapid and real-time flexibility from the service providers. With longer durations required from National Grid. These changes make the future frequency services contracts a less certain income stream for developers.

The potential for other non-energy storage generators to compete in this market is a further factor. For example, tests have shown offshore wind farms can provide the correct characteristics needed[36]. With over 5.1 GW operating and 4.5 GW under construction[37], offshore wind could provide significant capacity if called upon.

Together the greater need for frequency regulation, a high level of competition in any auctions, the changing format of these services, and the impact of non-energy storage developers, will make the response services market a challenging proposition for forthcoming energy storage projects over the next few years. Energy storage developers will have to accept a higher level of risk than they have done previously and be prepared to adapt their project design to meet the changing needs of the network. Gaining a contract will ultimately be more challenging and therefore should not be an assumed income stream to make the business model for an energy storage project 'stack up'.

2. How quickly will we see a roll out of domestic storage?

As we have discussed earlier the domestic market is at an earlier stage of development in comparison to other scales. This is evolving rapidly with the price per kWh installed dropping considerably over the last year. In addition, new solar PV and battery systems have a tax benefit - 5% rate of VAT (rather than 20%). Whereas a battery alone receives the higher 20% VAT rate. This

[35] National Grid, 2017 http://www2.nationalgrid.com/UK/Services/Balancing-services/Future-of-balancing-services/

[36] Dong energy, 2016 http://www.dongenergy.co.uk/news/press-releases/articles/dong-energy-wind-farm-demonstrates-frequency-response-capability

[37] Crown estate, 2017 https://www.thecrownestate.co.uk/energy-minerals-and-infrastructure/offshore-wind-energy/

could limit the retrofit of storage on the 800,000 existing solar PV systems in the UK.

The delivery of smart meters and half-hourly metering, will allow more variable time of use tariffs too be implemented. Half-hourly metering was made 'elective' (possible) in June 2017. To become widespread in the market this needs to be made mandatory. A decision on this is due in early 2018 would be beneficial, this is currently being consulted. This will significantly improve the financial benefit of owning a domestic system, as users will be able to avoid more expensive peak price periods (which could be 25p/kWh or more). In addition, the progression and increase in aggregator payments for use of domestic storage will impact the market.

Predicting the rollout of domestic storage is challenging, as the factors mentioned above will have a substantial impact. However, we have already seen thousands of installations, with little or no direct support from government. By extrapolating the number of installations we assumed for our demand scenario work for WPD, we could see 250,000 to 350,000 installations by 2030[38]. Regardless of the actual number, the market is likely to continue to grow and will be a key opportunity for SME's to target.

3. What impact might the growth of electric vehicles play and could they also become a storage solution through vehicle-to-grid applications?

In the recent smart systems and flexibility plan from government[39], there was mention of changes to enable vehicle-to-grid models and £20 million competition to accelerate development of the sector. This is an important intervention in the market and recognises that electric vehicles could have significant (positive or negative) impacts on energy infrastructure. The government is also seeking powers in the Automated and Electric Vehicles Bill to set standards for charge points.

[38] Regen, 2016 https://www.westernpower.co.uk/About-us/Our-Business/Our-network/Strategic-network-investment/South-Wales.aspx

[39] Ofgem/BEIS , 2017 https://www.ofgem.gov.uk/system/files/docs/2017/07/upgrading_our_energy_system_-_smart_systems_and_flexibility_plan.pdf

The National Grid Future energy scenarios have also provided further evidence of the growth in EV's and the importance of vehicle-to-grid applications. With up to 18 GW of extra capacity needed to manage the additional demand. Smart charging ability, the size of batteries in EV's and the extent of fast charging infrastructure, are all key factors in how the market develops.

The question is not whether EV's will be a storage solution, but how and when this will become widely available. Nissan are leading the charge on the rollout of Vehicle to Grid charging solutions[40] and their substantial presence in Sunderland will add weight to the progression of the technology. Questions remain on the ability of the network to provide enough capacity to meet the growth predicted. With smart charging solutions that manage peaks in charge/discharge a potential solution. Further development of this market is likely to be noteworthy.

4. What role might aggregators play in helping smaller players access the storage market?

The role of aggregators is going to be key over the coming years. Ofgem, the energy regulator, released a specific document on this subject in July 2017[41]. This document states the intention of the regulator to open up markets to independent aggregators, such as changing, 'some existing industry codes in order to allow access to the Balancing Mechanism (BM) and wholesale electricity market'. In some ways, this aggregator market is already functioning, with 1.4 GW of demand response secured from independent aggregators in the last capacity market auction in 2016[42]. However, with changes the impact of aggregators could be increased significantly. This could transform the

[40] Nissan, 2016 http://newsroom.nissan-europe.com/uk/en-gb/media/pressreleases/145248/nissan-and-enel-launch-groundbreaking-vehicle-to-grid-project-in-the-uk

[41] Ofgem, 2017 https://www.ofgem.gov.uk/system/files/docs/2017/07/ofgem_s_views_on_the_design_of_arrangements_to_accomodate_independent_aggregators_in_energy_markets.pdf

[42] Ofgem, 2017 https://www.ofgem.gov.uk/system/files/docs/2017/06/annual_report_on_the_operation_of_the_capacity_market_in_2016-17.pdf

aggregation market and provide benefits to domestic and commercial energy consumers.

One point to note is that the industry code changes required are done in opaque industry forums, dominated by the big energy companies, that are looking to maintain the status quo[43]. Consequently, the positive intentions of Ofgem and government could be tempered by vested interests.

Overall, aggregators are set to become a vital part of the energy storage market. The focus has been on commercial and industrial aggregation so far. As prices for domestic energy storage and the control systems require decrease, this will open up further opportunities for consumers to benefit and for aggregators to make their mark.

Figure 23: Nissan's R&D base in UK where Vehicle to Grid charging technology is being trialled.

[43] Regen, 2017 https://www.regensw.co.uk/news/ofgem-embedded-benefits-27-june-2017

5.3 Opportunity for Greater Manchester SME’s

The energy storage market is a potential growth opportunity for SME’s in Greater Manchester area and we have shown that some companies are already taking advantage. Below we discuss some specific barriers for SME’s, before commenting on the key opportunities.

Barriers for SME’s

Lack of market access - the energy storage and flexibility markets in general are due to grow. As in any market the price for a service is dictated by demand and supply. The value of flexibility is difficult to assess at the moment, as many smaller players are not allowed to gain access to the markets. As we have discussed the policy landscape is shifting to allow more people to access the market. However, in its current state many of the products and services that energy storage can access are overly complex and out of reach for many SME’s.

Energy companies investing heavily - many of the winning bids for the most lucrative energy storage contracts - Enhanced Frequency Response and the Capacity Market - have been from large energy companies. These companies can afford to invest money and time to get a good understanding of the energy storage market (potentially at a loss), in order to benefit in the long run as the energy storage market develops. This has also included movements into the domestic energy storage market[44] (see Figure 24). In general SME’s do not have the same ability to make these investments. Therefore, they are disadvantaged in this aspect of the market.

International competition - the energy storage market, like the energy sector, is international. This means companies that lead in certain regions of the world can bring their technology to the UK market. Similarly, UK companies can export their services worldwide when appropriate. In terms of capacity deployed, the UK energy storage market is less developed than other countries, such as the US and Australia. The UK market is open to businesses that have already developed a good product and service in other countries.

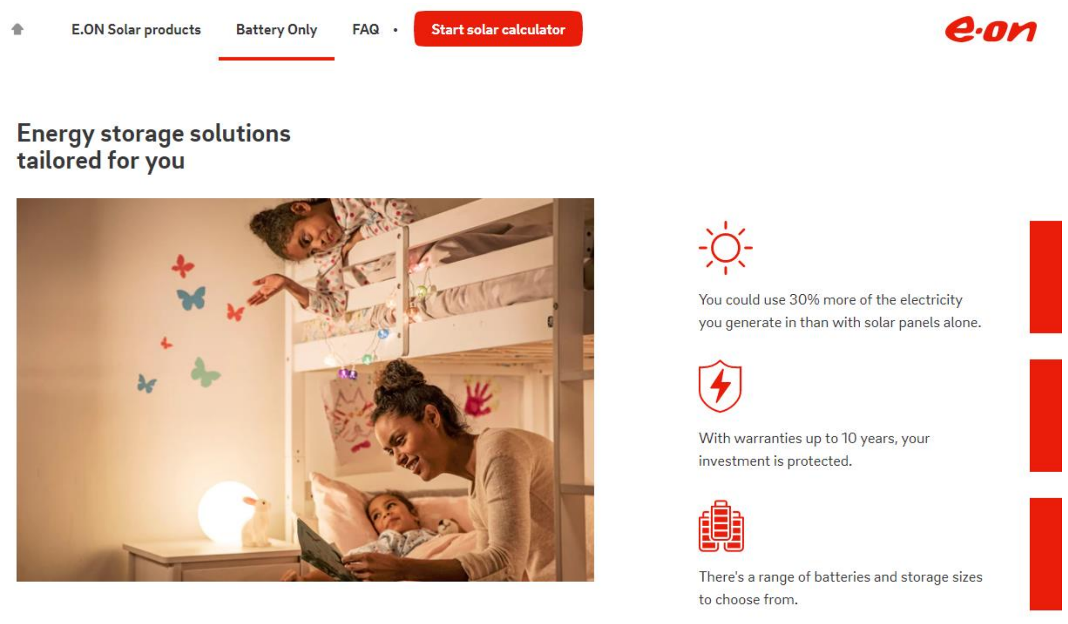


Figure 24: The E.ON solar and battery offer for domestic energy storage consumers in the UK (Source: www.eonsolar.co.uk) .

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[44] E.ON, 2017 https://www.eonsolar.co.uk/battery-only

Short-term opportunities for SME's

Having already covered a number of examples of SME's involved in energy storage in the Greater Manchester area, we will now discuss some of the main opportunities over the short-term, defined as now until 2020, the market value and potential for SME involvement (see Table 6).

Aggregation services – the area of aggregated flexibility is likely to be a big area of growth over the next few years as the regulatory framework is amended. SME's will have to compete with some of the large energy companies and international aggregators already active in the UK market. This could limit the potential opportunity in this area.

Energy storage feasibility – modelling the energy flows and providing high quality feasibility studies for potential energy storage projects, is another area of potential growth for SME's. Unfortunately, the market value is low due to the consumer expectation of low or zero cost quotations, associated with other technologies.

Grid connection works – as discussed earlier the grid infrastructure is a key part of potential energy storage projects. Getting a good connection for demand and supply, at a reasonable cost, is one of the key factors for grid scale energy storage projects and will continue to be moving forward. Specialist SME providers of these works could capitalise on this market value.

Control/communication systems – crucial to an efficient and effective energy storage project this will be a key area of the specification. Those companies that can provide the best products, with the flexibility to deliver different services and the compatibility with other systems, will be primed for growth. Competition from large existing manufacturers mean that the market value is more limited than it otherwise would be.

Operations and maintenance – as in the renewable energy sector, this area could become more significant as the capacity of energy storage deployed grows. As with any asset the proactive and reactive maintenance of the system is required to ensure performance over the lifetime of the products. Replacement of some components, cleaning of fans/filters may also be necessary. In the solar farm sector operations and maintenance is priced around £5,000 per MW per year[45].

Domestic energy storage installation - the majority of companies listed in the study area were defined as working directly in the installation of energy storage. We have divided this opportunity into the 'retrofit' – referring to adding energy storage onto existing solar PV systems, and 'new system with generation' - energy storage with some form of microgeneration, likely to be solar PV. The current opportunity and market value is greatest in new systems as there is a VAT benefit and better returns associated. SME's need to pick products to offer their consumers or become an installer partner for an existing scheme (see page 32).

[45] Solar Trade Association, 2017. Email from contact.

Innovation projects - there have been a whole range of innovation projects looking at various aspects of the energy network and how it can be improved. Energy storage has featured heavily among these projects[46] and is a good potential opportunity for SME's to get involved in the sector. Energise Barnsley is a community group involved in a UK example (see below). Innovation projects do not just run at the UK scale, but can occur at the EU level. Carbon Co-op[47] a Manchester based community group (see page 35), are involved in multi-million euro example that is installing energy storage directly into homes in Greater Manchester.
Local SME's have the opportunity of getting involved in these innovation projects by approaching these companies/groups and the other project partners and making sure they are aware of the capabilities of local companies in the area.

Commercial and industrial energy storage installation – the large potential for growth in this sector of the market, discussed previously, is likely to involve SME's. Many are already engaging with, or are themselves, within the commercial and industrial sector. Making this a reasonable opportunity for SME's. There are a number of players already active in the marketplace and access to finance/lease models are likely to be important.

Ancillary services – insurance, legal and planning - as with any new sector existing providers of services such as legal, planning and insurance are due to benefit from the growth of energy storage in some way. SME's can become or diversify into specialist providers of these services for energy storage, outcompeting conventional service providers. The contractual arrangements associated with energy storage projects are often more complex than other technologies. The impact of energy storage is relatively minor in planning terms, in comparison with other technologies such as onshore wind, but there is still likely to be work available.

Case study – Energise Barnsley innovation project

Moixa, Northern Powergrid and Energise Barnsley are working together to deliver an innovation project that brings together domestic batteries, solar PV and flexible demand.

The £250,000 project is funded by the Electricity Network Innovation Competition from Ofgem and is due to involve 40 homes in Barnsley. The properties are owned by Berneslai Homes, a local housing provider interested in the potential energy cost savings provided by the project.

The homes will be linked together in virtual power plant and the project will investigate the potential for domestic properties to become viable providers in this model.

www.northernpowergrid.com/news/home-battery-trial-aims-to-increase-electricity-network-capacity-to-enable-more-solar-homes-and-save-millions-for-customers

[46] ENA, 2017 http://www.smarternetworks.org/ProjectList.aspx?TechnologyID=7
[47] Carbon Co-op, 2017 http://carbon.coop/

Long-term opportunities for SME's

In addition, to the short-term opportunities up to 2020, there are some more speculative opportunities for SME's to utilise in the long term - 2020 onwards.

Recycling of energy storage components – the waste batteries and accumulators regulations[48], require those involved in the supply of batteries to offer recycling at end-of-life or on failure. The market for the recycling of energy storage components, most of which will be batteries, will grow as the market develops. This is a potential market for SME's as manufacturers and consumers will be looking for localised services. Plans for the UK's first battery recycling plant have recently been announced for Scotland[49].

Re-use of EV batteries – the re-use of Electric Vehicle (EV) batteries in energy storage has started to be discussed in the marketplace. For this to become more widespread more investment would be needed in the systems for repurposing of this waste stream. As both the EV and energy storage market continues to grow this is likely to become more popular. The potential for SME involvement is assessed as relatively low, due to the likelihood of this market being dominated by the large EV vehicle manufacturers, such as Renault and Nissan.

Optimisation of existing systems – similar to the solar PV sector, many early energy storage installations may need revisiting, in order to improve their performance. SME's are very well placed to deliver these services but the market value is likely to be quite low if the solar PV sector is anything to go by.

Summary of opportunities for SME's

As we have discussed, there is a broad range of opportunities open to SME's in the energy storage market, but also some significant barriers. Those that can specialise and provide niche services at a higher quality than international competitors will be at an advantage. Whereas others may choose to partner with larger manufacturers/developers and provide services for them. Competition will be considerable, but the predicted growth in the energy storage market, means that even a small market share is a big opportunity.

[48] UK government, 2017 https://www.gov.uk/guidance/regulations-batteries-and-waste-batteries
[49] Energy Live News, 2017 http://www.energylivenews.com/2017/08/16/scotland-to-be-home-to-uks-first-battery-recycling-facility/

Table 6: Analysis of energy storage market opportunities and the potential for SME involvement

Energy storage opportunity			Market value	Potential for SME involvement
Short-term (Now – 2020)	**Aggregation services**		High	Medium
	Energy storage feasibility		Low	High
	Grid connection works		Low	High
	Control/communication systems		Medium	High
	Operations and maintenance		Medium	Medium
	Innovation project involvement		Medium	Medium
	Domestic energy storage installation	**Retrofit**	Medium	High
		New system with generation	High	High
	Commercial and industrial energy storage installation		High	Medium
	Insurance		Low	High
	Legal work		Medium	Medium
	Planning consultancy		Medium	High
Long-term (2020 onwards)	**Recycling of energy storage components**		Medium	Medium
	Re-use of EV batteries		Medium	Low
	Optimisation of existing systems		Low	High

Appendix

Table 7: Potential revenue streams for energy storage (continued on next page)

Enhanced Frequency Response (EFR)	Firm Frequency Response (FFR)	Fast Reserve	Short Term Operating Reserve	Capacity Market
Similar to FFR but a faster response service to provide sub-second frequency response services. Service specifically targeted at battery storage providers with a high response capability. National grid tender for 200 MW announced in August 2016 that 8 EFR bidders had been awarded 4 year contracts using battery storage. Further tenders are expected. No aggregation. Pre-tender speculation suggested rates of between £20 and £40 per MW per hour of service. Auction outcome was however lower at an average of £9.40 per MW per hour with a range from £7-£11.97	Service to maintain overall grid frequency within a tolerance range of 50Hz. Service may be dynamic (constantly responsive) or static (trigger response). Service is tendered on a monthly basis and rates vary depending on service level, of which there are several. Short term tenders – 1-23 months although most > 6 months. Suitable for battery applications, response within 10 sec (primary) or 30 sec (secondary) and sustained for up to 30 mins. 10 MW minimum but can be aggregated. Potential also for Demand Response - FCDM.	Fastest reserve service, 2 minute response to unexpected demand increase or loss of generation. Service utilisation for a up to 15 min (or as specified) unit but generally <5 minutes Contract duration 1-23 month (can be up to 10 years) but typically < 6 months. Morning and evening availability. Minimum capacity 50 MW but aggregation is possible through an integrator. Relatively small market and few current providers. Complex payments for availability, positional, nomination and utilisation. Potential for Demand Response.	Short term and a slower reserve service. 3 MW minimum but typically 10-15MW. Ramp up within 20 mins desirable to win contract, typically asked to maintain energy output for a minimum of 2 hours and a recovery within 20 hours. 3 seasonal auctions, seasonal & daily time periods. Payments for availability £/MW/hr and utilisation £/MWh. Prices and revenues have been falling suggested increased competition. Revenue is uncertain depending on availability and utilisation. Competitive threat from diesel generators. Potential for Demand Response.	The Capacity Market instrument to secure existing, and incentivise, new capacity to maintain capacity margins. In return for capacity payment revenue, generators must be available to deliver energy at times of peak demand or system stress. Annual auction tender for future years capacity. Duration varies – longer for new capacity. UK 2015 T4 tender for 2019/20 lower than expected at only £18 per KW. The pre-qualification for the 2016 T4 tender has been announced and includes over 4 GW of storage capacity of which over 2 GW is new build battery storage. Competitive threat from diesel generators.
Relative value – High	Relative value - High	Relative value – Med/high	Relative value - Med	Relative value – Med
Based on 2016 EFR auction outcome: annual Revenue £60-£105k per MW per year	Varies according to service. Rough estimate £40-150k per MW per year depending on service and hours tendered.	Difficult to estimate for a storage provider new entrant. Very rough revenue estimate £50-70k per MW per year based on analysis of National Grid 2015/16 market data.	Combined annual potential revenues circa £20-35k per MW per annum (assuming availability). Based on 2014/15 and 2015/16 total STOR expenditure Ref National Grid Service Reports	£20-35k per MW per year, possibly higher, depending auction* outcomes. *UK 2016 T4 (Dec) tender price is expected to be higher than 2015

Transmission cost avoidance	Distribution cost avoidance	Generator "own use" (domestic and non-domestic)	Generator Grid Curtailment	Price arbitrage (& peak shaving)
The cost of UK transmission network is charged to generators and demand users via a number of mechanisms. Demand based charges (73% of total charges) are mainly recovered through the Transmission Network Use of System (TNUoS) & Balancing Services Use of System (BSUoS). Both are based on peak time demand – for TNUoS this is calculated using the "TRIAD" peak demand periods. There is a value in using storage to reduce net demand during the peak time & TRIAD periods to avoid these charges. Revenue could come in the form of payments from energy off-takers ("Embedded Benefits") or cost saving for high energy users.	The cost of running the distribution network is recovered from generators and demand users. Energy storage and distributed generators can therefore offset demand earning a credit from DNO's, or offsetting high energy users costs. For intermittent generation the credit is a flat rate, for non-intermittent the credit is time banded and are highest during the peak demand period "Red Zone" (4-7pm daily) and in the winter period "Super Red Zone". The value is greatest if connected at the Low Voltage network and varies (greatly) by region.	Located alongside variable generation such as PV and wind, energy storage could be used to store energy during peak generation periods and deliver energy during periods of user demand. Value for the energy user comes from maximising their own use of generated electricity, avoiding the peak price for electricity during high demand periods. An example would be charging batteries linked to solar PV during the day, and time shifting the energy to the early evening peak when costs are highest. This will be facilitated by the roll-out of smart meters and "time of use" tariffs (TouT).	Energy storage could be used to store, and time shift energy which would otherwise be "lost" due to grid curtailment. This opportunity has grown due to the increase in constraints in the distribution network especially in high renewable energy regions and the increase in constrained grid connection offers. An alternative value would be avoidance of grid reinforcement. This could potentially be combined with an "own use" high energy user or as a standalone application co-located with an energy generator.	Although co-location alongside energy generation and a high energy users would deliver greater value, it is also possible that energy storage could be used simply to exploit price variance in the energy market. Storing energy during low price periods for delivery during peak price periods. Wholesale price variance in the UK ranges from <£20 MWh during low demand periods to £80 MWh plus during the peak. Extremes of negative pricing and very high spot prices have also become more common.
Relative value – Med/high	Relative value - High	Relative value – Low	Relative value - Low	Relative value – Low
Potentially a good revenue stream especially if the TRIAD periods are successfully targeted.* Together TNUoS, BSUoS and transmission loss embedded benefits or cost savings could be worth £40-50k per MW per year.	Potentially attractive. depending on location and how energy storage is treated by DNO's*. Potentially £40-80k per MW per year in south west England however see note below.	Low relative value because a relatively high storage capacity is required to store variable generation and capture revenue from daily price variance between wholesale and retail tariff.	Combined with own use would deliver higher value but a relatively high storage capacity (and therefore capital cost) is needed to meaningfully time shift generation.	The challenge for energy storage is the capital investment required to store significant energy capacity to effectively price arbitrage.
*Note: The mechanism to recover transmission costs is expected to be overhauled and the future of TRIADs is uncertain – see "Paying for our grid"	*Note: changes in the way DNUoS charges are calculated will significantly reduce peak time cost savings from 2018 onwards.			