Energy Storage Growth Scenarios and Operating Modes Consultation

Summary report of results and feedback received

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Photo credits

WPD would like to thank and credit *British Solar Renewables*, *BYD*, *Regen* and *National Grid* for use of their images and graphs.

Contents

1 – Introduction & Consultation Background

Consultation on Energy Storage

WPD has been working with Regen to develop an approach to model the growth and operation of storage. As part of this modelling work, we developed and issued a consultation paper, aiming to help us to validate some of the key assumptions we have made in this modelling approach.

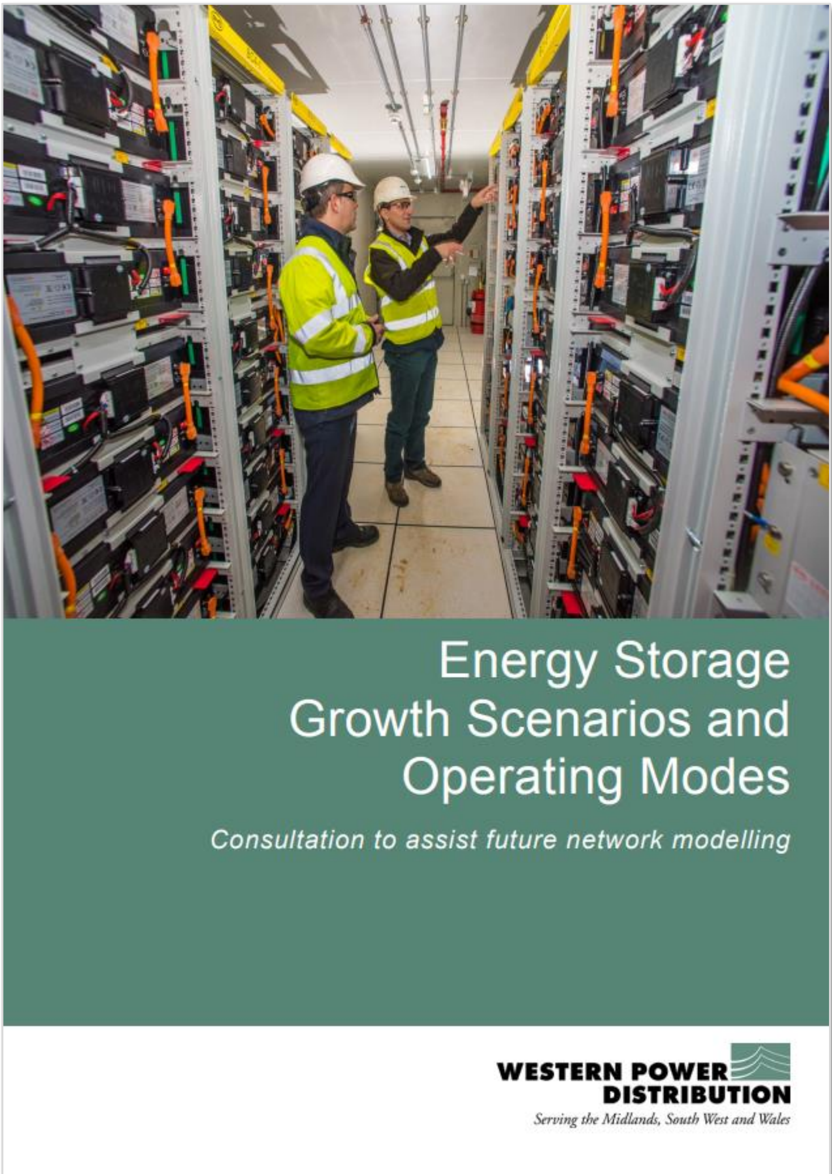

Figure 1 – Energy storage growth scenarios and operating modes – consultation paper
https://www.westernpower.co.uk/About-us/Our-Business/Our-network/Strategic-network-investment/Energy-Storage.aspx

This consultation was issued on 15th May 2017, was open to responses for 6 weeks and closed on 21st June 2017.

In undertaking this consultation, WPD was seeking to understand:

- *The potential scale of growth of energy storage within its distribution network*
- *The type of energy storage assets/projects that are likely to be deployed within its network and their business models*
- *The typical operating behaviour of storage assets, how they are likely to be used and their typical mode(s) of operation*

WPD wished to consult with industry to establish whether the analysis and definitions WPD and Regen had arrived at around storage business models, project specifications and operating modes were appropriate and reflect how the sector currently views the likely deployment and operating behaviour of storage.

We have had a positive response to this consultation, with a broad range of respondents from across the industry providing a breadth of response and levels of insight around the growth, technology, technical specification and operation of energy storage. The graph below shows the split of the **27** parties that responded:

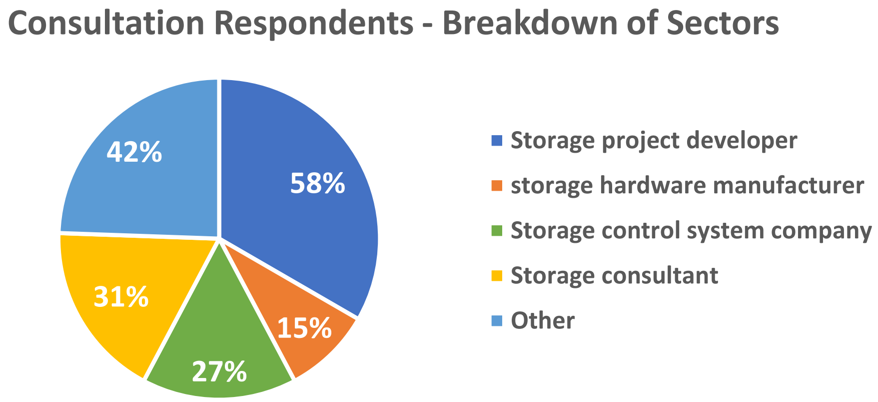

Figure 2 – Graph of the breakdown of organisations that responded to this storage consultation

WPD would therefore like to thank everyone who responded to this consultation, the information gathered has been used to inform our future network planning and has helped us further understand the growth and operation of storage in more detail.

We would welcome further engagement with the industry as energy storage technology, interest and commercial drivers continue to progress.

This report shares the original background, analysis and assumptions we have made around storage, specifically in the areas of growth, technical specification and operation. It also shows a summary of the response we have received, with anonymised results against each of the 20 questions from the consultation, as an aggregated summary. As a result of the feedback we have received through this consultation, the report concludes with an outline of some of the specific areas where we have adjusted our network modelling assumptions and some key principles that WPD wish to implement, to ensure the benefits of energy storage can be realised on its network.

2 – An Introduction to Energy Storage

The value of flexibility

The UK energy system is undergoing significant change and the value of flexibility within the system has increased in line with this ongoing evolution of the system. In November 2016, BEIS and Ofgem issued a joint call for evidence around '*A Smart, Flexible Energy System*' and energy storage featured extensively throughout this call for evidence, as an area that could promote and increase the inherent flexibility in the energy system. BEIS and Ofgem have since published a '*Smart Systems and Flexibility Plan'*, where a number of regulatory changes around the classification/ definition and the network charging structure for storage assets are being amended.

As part of the drive to improve the balancing of generation and consumption, maximise the use of low carbon energy generation and optimising the investment in infrastructure, flexibility technologies such as storage could be a key enabler.

The role of energy storage

Energy storage is a technology area that is well placed to support the needs of the changing energy system, specifically around flexibility and security of supply. As a concept energy storage is not new, with technologies such as pumped hydro, flywheels, heated water tanks and others storing energy for use on demand.

The role of energy storage is changing due to the changing market, technology costs, need for flexibility services and the development of more sophisticated control systems to integrate, aggregate and manage storage assets. There are a number of roles energy storage can play (such as backup mains supply). The categories that we believe will see the biggest growth, are energy reserve services, response services and energy time/price shifting. See below summary of these services:

- ***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.

As part of this consultation, we took these core roles of storage and categorised them into a set of key emerging business models. A summary of these business models can be found on page 19 of this paper.

Growth of the energy storage market

The storage market has come up against a number of barriers to progress, ranging from technology constraints, high up-front cost, uncertain revenue streams, potential for constrained connections and changing regulation. However, despite this inherent complexity, there is a strong consensus that energy storage could see rapid growth in the coming decades and become a critical part of the overall UK energy system.

The current growth in interest in energy storage has been driven by:

- The expected fall in storage equipment costs, in particular, batteries
- The need for higher levels of flexibility and network ancillary services caused by the increased penetration of variable renewable generation and the closure of existing thermal plant
- The availability of revenue streams for balancing and ancillary services and the need for storage to play a key role in Demand Side Response (DSR)
- The parallel slowdown in development of renewable energy (onshore wind and solar PV), which means that resources and capital are available for new investment opportunities
- The emergence of new business models, which are discussed in more detail in the Regen report - *Energy Storage: Towards a Commercial Model*

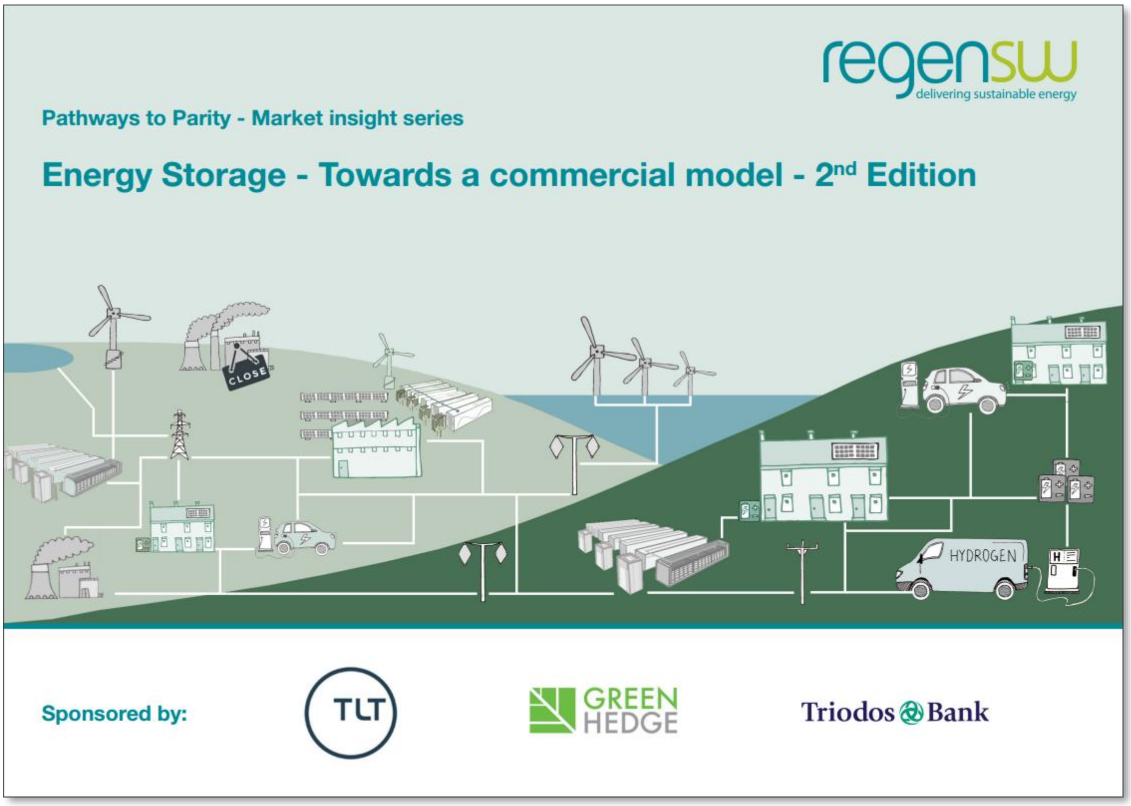

Figure 3 – Energy Storage - Towards a commercial model (2nd edition) available at https://www.regensw.co.uk/storage-towards-a-commercial-model *Credit: Regen, 2016*

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Future Energy Scenarios for Energy Storage

On 13th July 2017, National Grid published the latest version of their *Future Energy Scenarios* (FES) strategic document. This document considers and discusses the role of energy storage in the future in 4 key energy scenarios. 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. 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. See Fig.4 below.

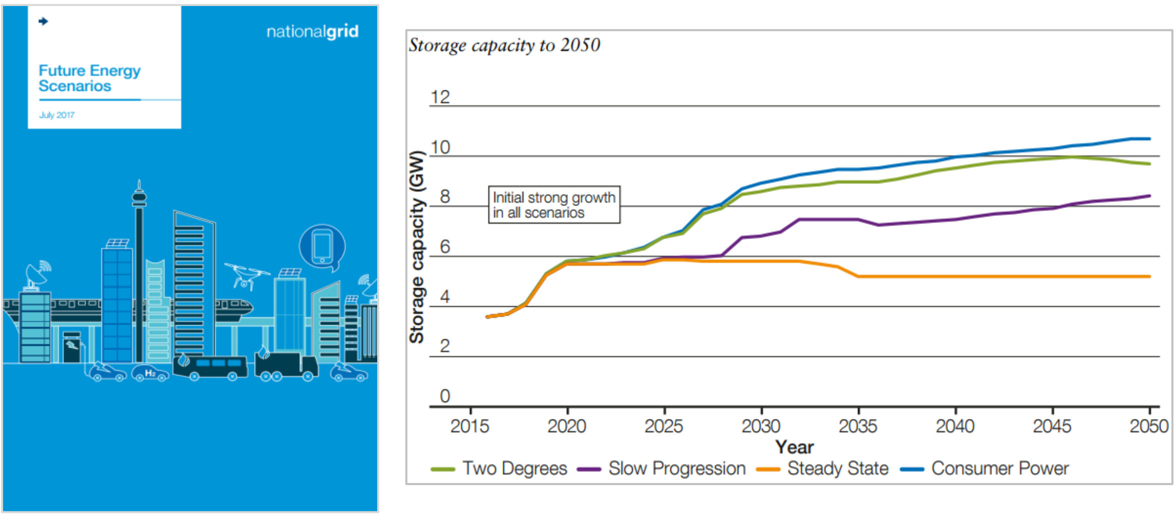


Figure 4 – National Grid FES available at http://fes.nationalgrid.com + electricity storage capacity to 2050

These values fall within WPD's High and Low Growth Scenarios as detailed on p.11. National Grid do suggest that a higher storage capacity could be required under a series of sensitivities, with a *Consumer Renewables* sensitivity proposing c.42 GW of storage capacity potentially coming online, if 65% of generation is decentralised.

The regulatory barriers identified by National Grid have been carried forward into the 2017 FES and include the removal of some 'double charging' of storage and a definition of storage assets, distinguishing it from other generation. Some of these changes are being proposed to be fulfilled, through BEIS and Ofgem's joint '*Smart Systems and Flexibility Plan*' published 24th July 2017, potentially removing some of the barriers preventing significant storage growth from occurring.

Increasing interest in storage connections

WPD has received unprecedented interest in connecting storage assets. The volume of grid connection applications has both significantly increased and seen notable fluctuation in the past 12 months. As shown in Figure 4, a total of 1,832 MVA (across 122 sites) of connected, accepted and offered storage capacity is on our network, with a further 2,063MVA (across 104 sites) of enquiries are also on our register.

	Connected		Accepted		Offered		*Enquired*	
Supply Area	**Number of Sites**	**Capacity (MVA)**	**Number of Sites**	**Capacity (MVA)**	**Number of Sites**	**Capacity (MVA)**	***Number of Sites***	***Capacity (MVA)***
West Midlands	1	3	38	802	16	259	*6*	*126*
East Midlands	0	0	20	278	15	222	*47*	*883*
South Wales	0	0	1	0	2	4	*1*	*3*
South West	0	0	17	208	12	55	*50*	*1,051*
TOTAL	**1**	**3**	**76**	**1,289**	**45**	**540**	***104***	***2,063***

Figure 5 – WPD Generation Capacity Register data for storage, dated 3rd July 2017

The graph in Figure 5 shows that across our 4 licence areas over the past 12 months, the volume of storage applications that have received, but not yet accepted, connection offers has dropped, notably in recent months. Whereas the graph in Figure 6 shows the volume of applications that have accepted offers but not yet connected their projects has seen a steady increase in the last 12 months.

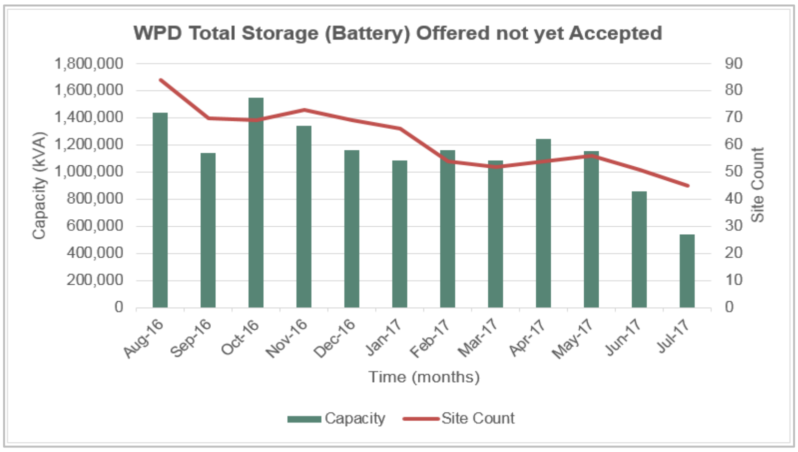


Figure 6 – Battery storage projects offered but not yet accepted (Aug 16 – July 17)

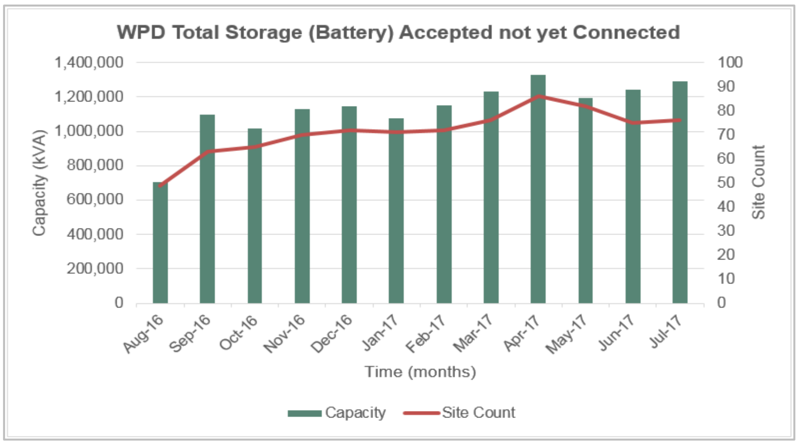


Figure 7 – Battery storage projects accepted but not yet connected (Aug 16 – July 17)

Connection agreement process for storage

In addition to the established connection application process for other technologies, the Energy Networks Association (ENA) have developed a form that captures specific technical information for the connection of storage projects.

This *Energy Storage Further Information Request* form is available at http://www.energynetworks.org/electricity/futures/energy-storage/energy-storage-further-information-request.html and is designed for any applicants that are considering the inclusion of storage as part of their connection application.

It asks a series of questions around the electrical specification of the applicant's Energy Storage System (ESS), ranging from specifying the storage technology and the co-located generation technology (if any), to requesting information around the operating modes or commercial service of the storage system.

WPD has recently published guidance on connecting energy storage to its network, available on the storage section of our website, available here: https://www.westernpower.co.uk/Connections/Generation/Energy-Storage.aspx

This page has links to a short video around how storage may interact with our network in the future (see Figure 8) and features a link to our document – *Guidance on the connection of energy storage devices to Western Power Distribution's Distribution System* (see Figure 9).

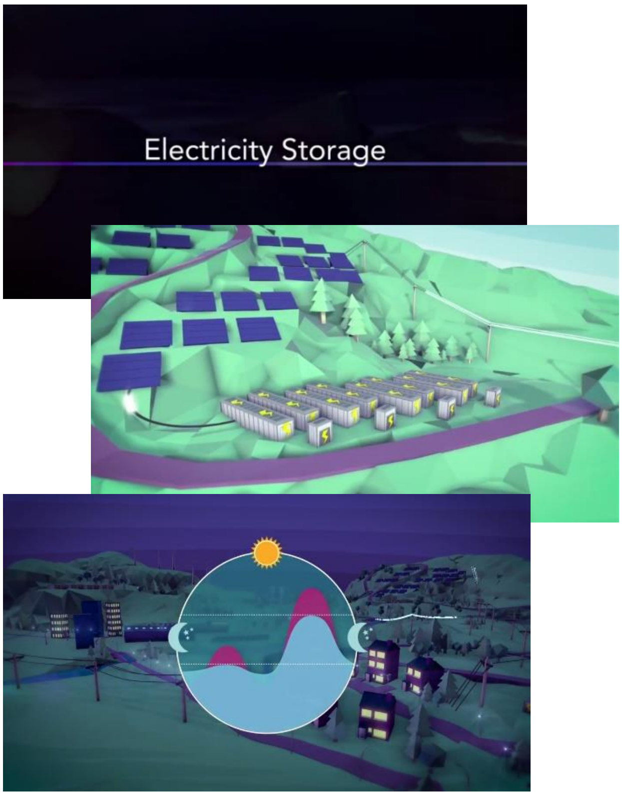


Figure 8 – Electricity storage online video, available here: https://www.youtube.com/watch?v=PPbIzAu_7d4

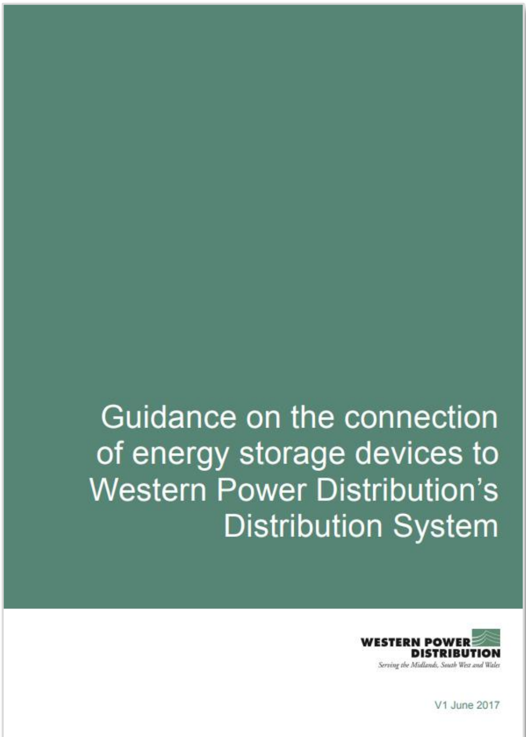


Figure 9 – Energy storage connection guide, downloadable here: https://www.westernpower.co.uk/docs/connections/Generation/Energy-Storage/Energy-Storage-Guidance-Final-June-2017.aspx

3 – Consultation Section 1 Results: Storage Growth Scenarios & Business Models

Overall storage market growth scenarios to 2030

Many industry analysts are predicting a rapid market growth for electricity storage and other forms of flexibility in the next decade. In order for this rapid growth to materialise, there is a need for steps to be taken to facilitate market innovation, with an early focus on battery storage.

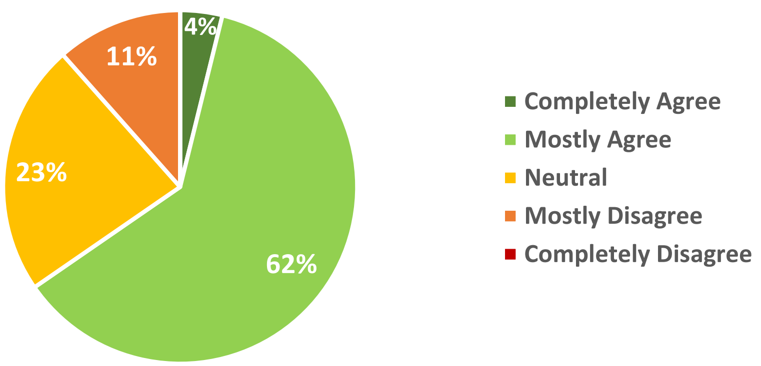
A number of market analyst's reports have projected energy storage growth scenarios, these include National Grid *Future Energy Scenarios (see Fig.4)*, Committee on Climate Change, Carbon Trust and UK Government.

As a starting point for WPD's modelling, we are proposing to take a:

- **High growth** scenario of **10-12 GW** and **24-44 GWh** of energy storage capacity installed across GB by 2030.
- **Lower growth** scenario of **4-5 GW** and **6-15 GWh** across GB by 2030.

Note: these figures include 2.7GW of existing pumped hydro storage.

Question 1 - ***To what extent do you agree with the high and lower growth scenarios for storage we have identified above?***



Question 1 - summary of comments received:

Of the neutral and mostly disagree responses, the majority suggested that the lower growth scenario was conservative. The introduction of significant number of electric vehicles under "Vehicle-to-Grid" (V2G) arrangements could be one factor that results in storage deployments levels increasing above the values we proposed.

However, other comments received also identified regulatory barriers as a key factor that could perhaps limit deployment to levels potentially even beneath the lower growth scenario proposed. The wide margin between the high and low growth scenarios presented was recognised as an accurate reflection of market uncertainty.

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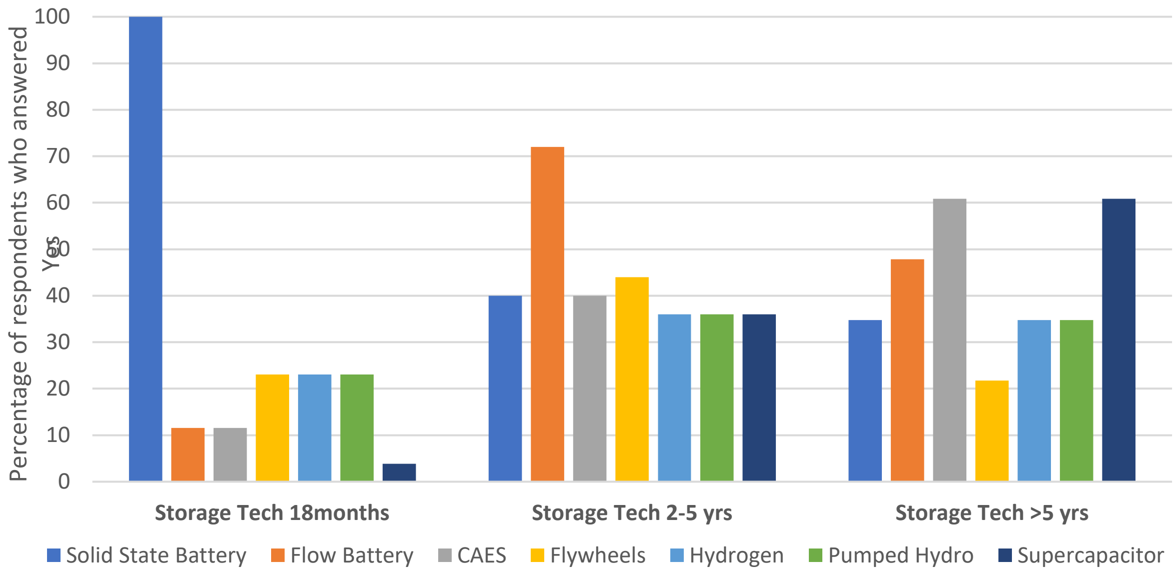
Question 2 - *What energy storage technologies do you think will be deployed?*



Summary of comments received:

The results show a significant favouring of solid state batteries in the short term, and a fairly even spread of the proposed technologies in the medium and longer term. Interestingly, flywheels have been predicted to be significantly more popular in the 2-5 year time frame than for >5 years. None of the proposed technologies have received significantly less attention than the average.

The answers received suggest the market is interested in some technologies that were omitted from the consultation. There are liquid air (and other cryogenics such as hydrogen) and thermal storage. In addition, comments were offered on the nature and development of solid state batteries, likely developing from lithium to include nickel-based and ceramic batteries, as well as high temperature batteries such as sodium sulphur.

Development of the energy storage market

The 2016 Enhanced Frequency Response (EFR) and T4 Capacity Market auctions jump-started the electricity storage market development in the UK and WPD has received unprecedented interest in connecting storage assets.

The first 'wave' of connected storage assets appear to be focussing on frequency response, Capacity Market, demand side response (DSR) and potentially other grid and network services. In a high growth scenario, WPD'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.

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.

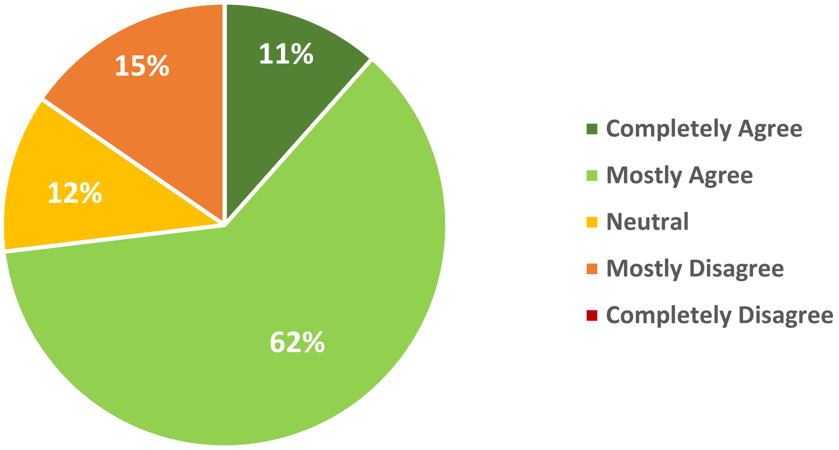
Wave 2 - Co-location business models become viable (Early 2020's)

- 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.

Question 3 - *Assuming a high growth scenario, to what extent do you agree with the waves of deployment of storage we have outlined above?*



Summary of comments received:

Although broad agreement is expressed regarding the waves of deployment proposed, some respondents suggested that these waves, or some aspects of them, may occur sooner than described in the proposed timeframes. In particular, we received feedback that some business models listed in waves 2 and 3 are in-fact being explored currently, as secondary income streams for projects in wave 1, as developers are looking to maximise asset value.

V2G storage systems were mentioned here also, though comments suggested that their role will depend on regulatory and legal factors, as well as logistical considerations - such as infrastructure.

Location of energy storage projects

WPD's analysis of the grid connection applications suggests a number of factors which affect the location of energy storage projects. These include:

- ***Access to grid (specifically 132kV and 33 kV substations)***
- ***Proximity to C&I energy demand***
- ***Proximity to new and existing solar PV***
- ***Proximity to other existing generation plant***
- ***Availability of low cost and accessible land space***

These factors have tended to concentrate connections close to the high voltage (HV) network. We have also noted some storage projects wishing to connect to the low voltage (LV) network.

WPD Network Capacity Map

To assist storage and generation developers, WPD have now launched a new interactive online ***Network Capacity Map***, which is available at: www.westernpower.co.uk/Connections/Generation/Network-Capacity-Map.aspx

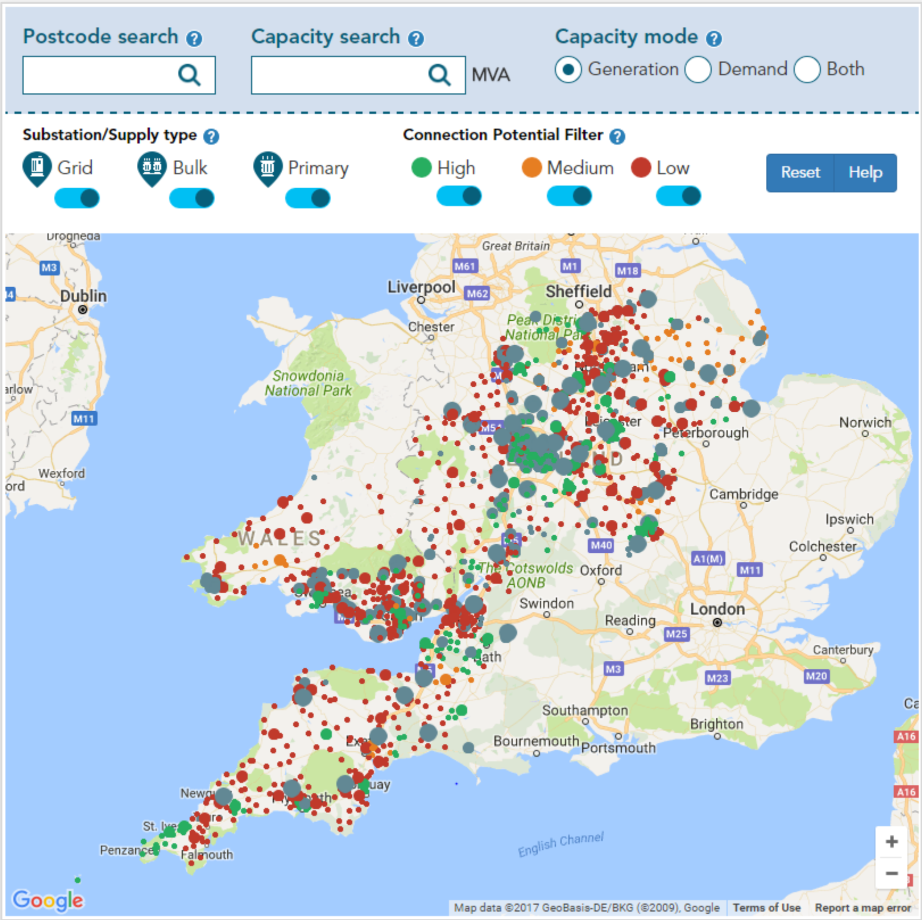


Figure 10 – WPD online Network Capacity Map

We would welcome any feedback on this new online tool.

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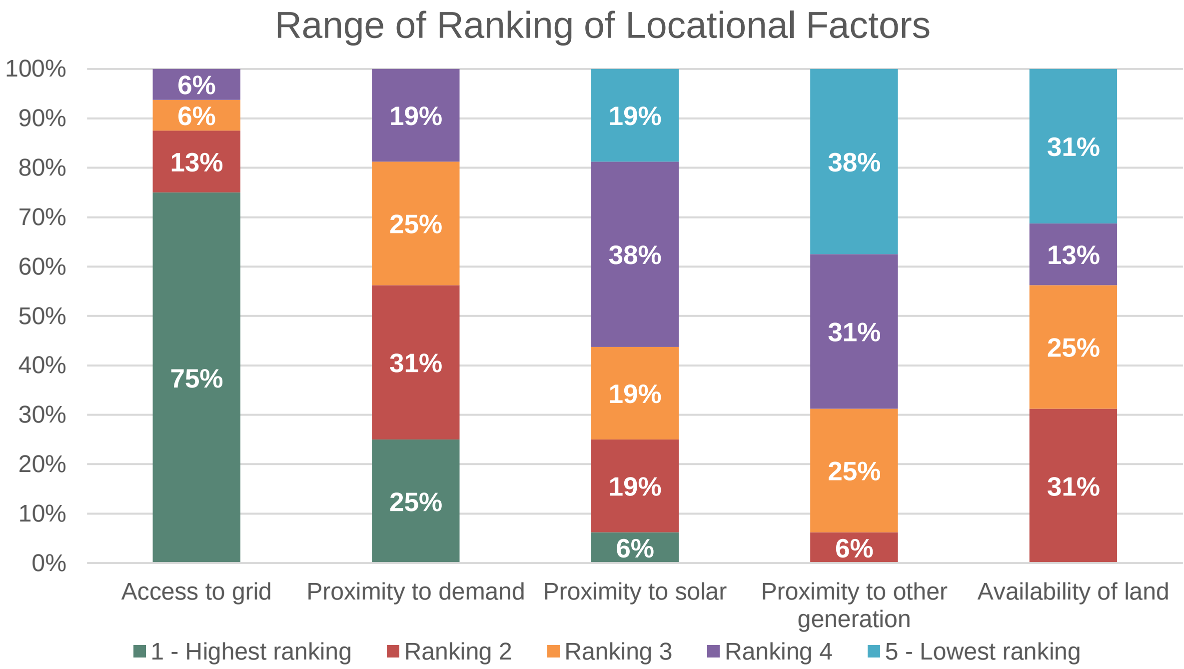
Question 4 - ***Based on the key factors determining the location storage projects we have identified in Table 1 below, we have ranked these by importance. Would you rank these factors differently? If so, how?***

Table 1. WPD's ranking of identified locational factors

Access to grid connection point	**1**
Proximity to energy demand	**2**
Proximity to existing/new solar PV	**3**
Proximity to other existing generation plant	**4**
Availability of low cost and accessible land	**5**



Summary of comments received:

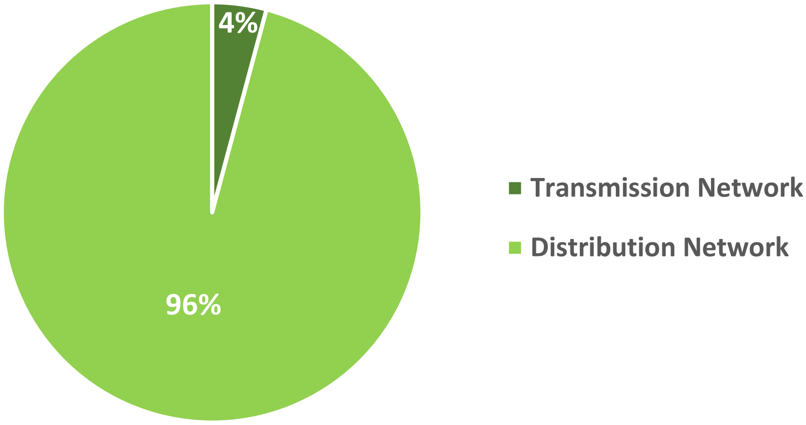
The analysis of the responses to Q4, showed that more than a third (37%) of respondents agreed with our proposed ranking shown in Table 1.

Half of those who proposed alternative rankings, also put 'Access to grid' as the highest priority. With proximity to other generation and availability of land, coming through as the least important locational factors.

The stacked bar graph above shows the proportion of which factor was rated in what order by the respondents, showing some dispersed rankings, reflecting the range of

Further feedback we received referred to some other distinct locational considerations, namely the extent of grid constraints in given locations, DUoS and TUoS charges applicable to location, as well as *localised* procurement of network balancing services from storage, as network investment deferral. This is a key area that we are considering, as the storage market continues to evolve.

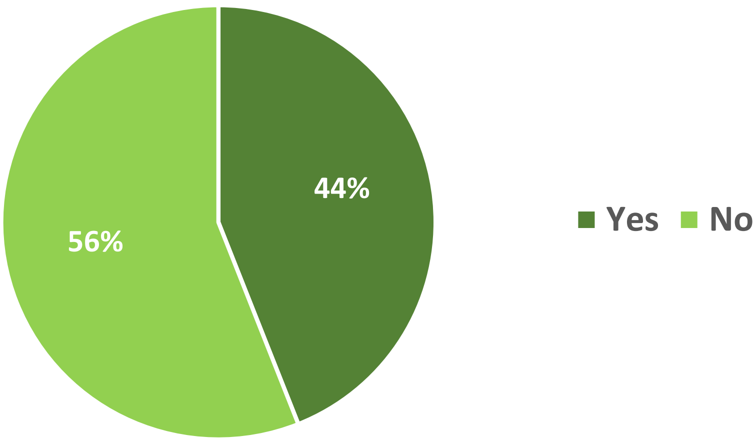
Question 5 - ***Which network do you believe will see the most connected storage capacity?***



Summary of comments received:

The overwhelming consensus was that storage capacity will be predominantly connected to the distribution network – which we feel has been reflected in both the volume and nature of connection applications WPD and other DNOs across the UK have received, over the past 12 months (see Page 9 of this report).

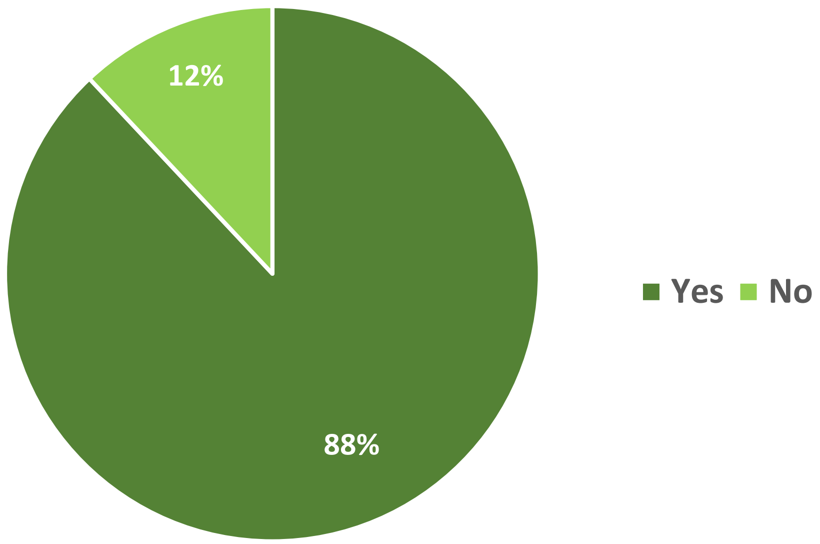
Question 6 - ***Have you made use of WPD's new network capacity map? If so, have you found this online tool useful?***



Summary of comments received:

Whilst more respondents commented that they had not used the online map to date, those who had, expressed the significant value of the map to their early project planning/feasibility stages. A number of revisions were suggested with regards to the information available on the online map. WPD are reviewing these from the perspective of improving the application process for storage developers where possible.

Question 7 - ***Do you think you might use this tool in the future? If so, how?***



Summary of comments received:

Significantly more respondents advised that they would make use of the map in the future. Comments received suggested that some respondents had not yet made use of this online tool due to lack of awareness and/or its value for high level feasibility assessment for storage projects. Other comments received also referenced the relative immaturity of the storage market, potentially only now causing the map to become relevant to storage developers.

Energy storage business models and class of projects

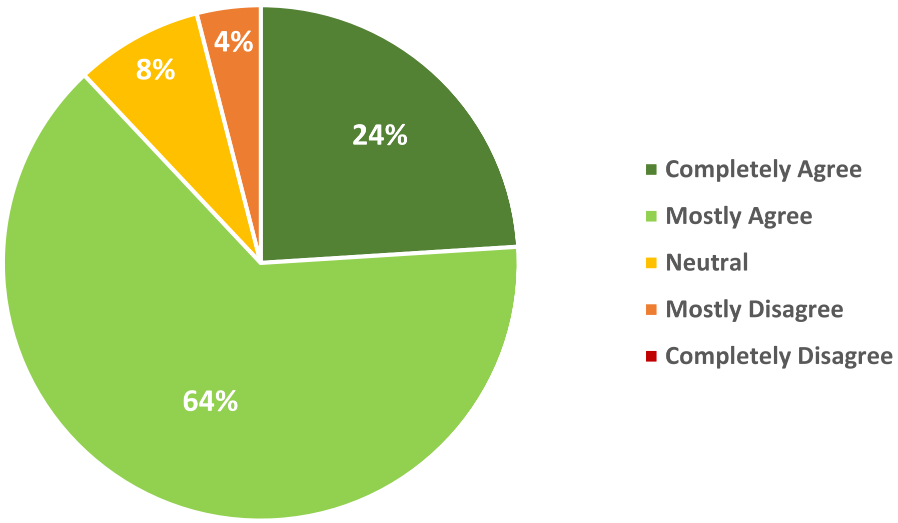
The nature of energy storage is that it can be used in a very wide range of applications and can therefore access a number of revenue streams. The concept of revenue stacking, (putting together multiple benefits/income streams to create a viable business case), has led to a proliferation of potential business models.

To simplify and provide a basis for our analysis, WPD has grouped/classified energy storage assets into 5 main storage asset types, based on their core 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

We recognise that there are potentially other business models to which energy storage could be applied, including aggregation models, trading platforms, local supply and private wire (including virtual private wire) models.

Question 8 - ***To what extent do you agree with the 5 key business models for energy storage assets, that we have outlined above?***



Question 9 - ***Are there other core business models for storage that WPD should be considering, which would have a significant impact on the network?***

Questions 8 & 9 - summary of comments received:

88% of responses falling into the 'Completely Agree' or 'Mostly Agree' categories showed broad agreement with the core business models we have proposed.

Analysis of the comments received showed a trend in discussion around both the 'stackability' of revenue/income streams, as well as the overall aims of investing in storage to both defer investment in the network and to alleviate network constraints.

Whilst there was also discussion around more bespoke or more detailed variations of the core business models we identify on page 19, discussion around a 6th key business model where aggregated storage capacity could be combined to secure balancing service contracts, market trading or other services, was identified. WPD will consider this additional business model of 'Energy Trader/Aggregator' in its strategic network modelling around storage.

4 – Consultation Section 2 Results: Storage Asset Characteristics

WPD recognise that every storage project will be unique, but based on the business models and classifications, we have made some generic assumptions about the typical characteristics of storage assets.

The purpose of consulting on these characteristics, is to inform WPD in undertaking its high-level network modelling, it is not intended to be used to inform constraint analysis on any individual projects.

Power and Energy Ratios

The ratio of **storage power output (MW) to storage capacity (MWh)** is a key characteristic of a storage system and can vary depending on the business model that is driving the specification of the storage asset.

If storage is co-located with generation, we have also made some assumptions around the ratio of **storage power (MW) to generation power (MW)**, by technology. These ratios are only applicable to some of the business models

If storage is installed alongside demand, we have made some assumptions around the ratio of **storage power (MW) to peak demand (MW)**, at both domestic and C&I scale. Again, these ratios only apply to some business models.

The below tables outline the assumptions we have made around these ratios, showing storage power as the **reference value** and the ratio to storage energy (now and at 2030), generation power capacity and power demand, against the 5 business models:

Business model	Storage Power [MW]	Storage Energy [MWh]		Generation Capacity [MW]	Peak Power Demand [MW]
		Now-2020	By 2030		
1. Response service	1	*0.5*	*1*	--	--
2. Reserve service	1	*3*	*4*	--	--
3. Commercial & Industrial	1	*3*	*4*	--	*1*
4. Domestic & Community	1	*2*	*3*	*1*	*0.25*
5a Generation Co-Location Solar	1	*3*	*4*	*1*	--
5b Generation Co-Location Wind	1	*6*	*8*	*2*	--

Figure 11 – Table of assumed Power and Energy Ratios

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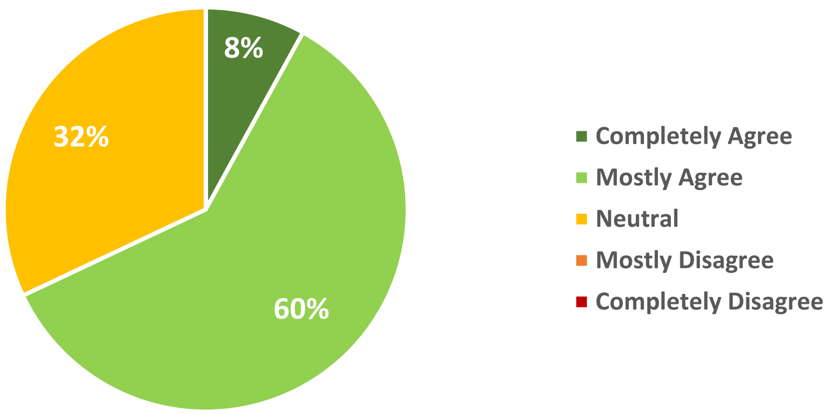
Question 10 - *To what extent do you agree with the ratios of power to energy (MW:MWh) that we have assumed for each of the business models both now-2020 and out to 2030, in Fig.10?*



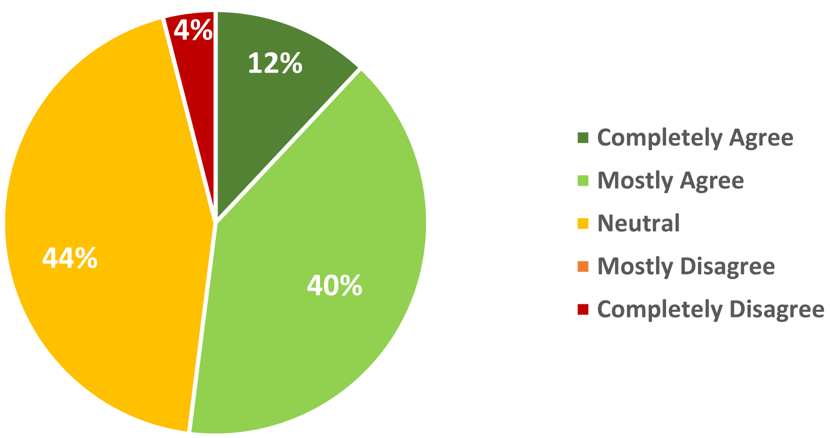
Summary of comments received:

Some uncertainty was expressed with regards to the Storage Power-to-Energy ratios that we proposed in Fig.11, with 32% answering neutrally (neither agree nor disagree).

A general agreement was conveyed in the comments received, that the MWh element of the ratios will increase as time goes on. However, of those answering ‘mostly agree’, a variety of alternative ratios were suggested, some being lower than those suggested for Response Service storage assets and others being higher energy capacity (i.e. Generation Co-location (wind)). The relatively high number of neutral responses highlights the level of uncertainty regarding future business models.

WPD will be adjusting the ratios of some of the business models in its network modelling for storage, as a result of the feedback we have received (see Fig.12, p.34).

Question 11 - *To what extent do you agree with the ratios of storage to generation power (MW:MW) we have assumed for the two co-located technologies in Fig.6?*

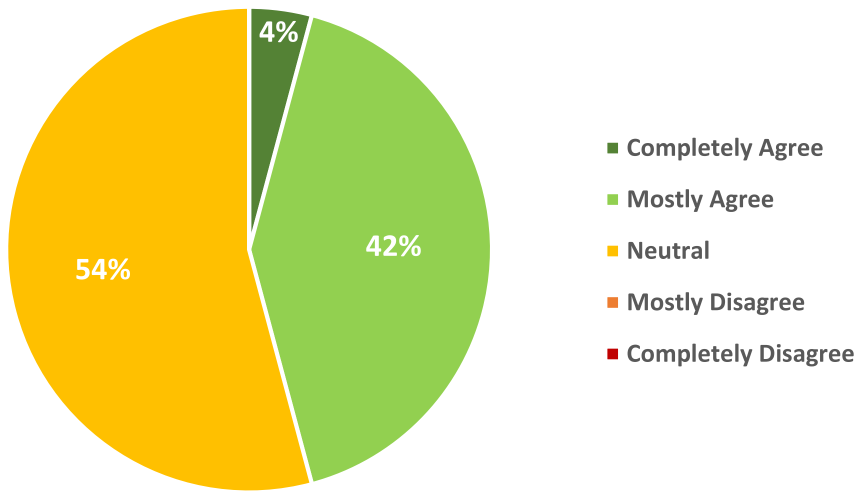


Question 11 - Summary of comments received:

There was a high degree of uncertainty with regards to the Storage Power-to-Generation Power ratio, with more than a third (44%) of respondents answering neutrally, this was noted partially as a level of technical detail that some were unable to comment on, and uncertainty regarding future business models.

Where some respondents disagreed with the proposed ratios, the suggestion was made that higher values could be assigned to these ratios (for both solar and wind).

Question 12 - ***To what extent do you agree with the ratios of storage to demand peak (MW:MW) we have assumed at domestic and C&I scale in Fig.6?***



Summary of comments received:

With further neutral answers received for the ratio of Storage Power-to-Peak Demand, the comments received suggested that the ratio for storage power to demand peak power might be higher than the values proposed, suggesting that demand peak could be significantly higher than the power rating of the storage asset, with the highest suggestions in the region of 1:10/15.

Other feedback we have received includes the consideration around using average demand, rather than peak demand as the reference value for storage power sizing, as some respondents felt that peak demand may be an irregular occurrence and the relevant sizing of a connected storage asset should potentially reference more regular average demand, rather than unrepresentative demand peaks. WPD will consider this.

The role of energy storage as back-up provision for a demand site (as an alternative to diesel generation for example) was also discussed.

Energy Depth of Discharge

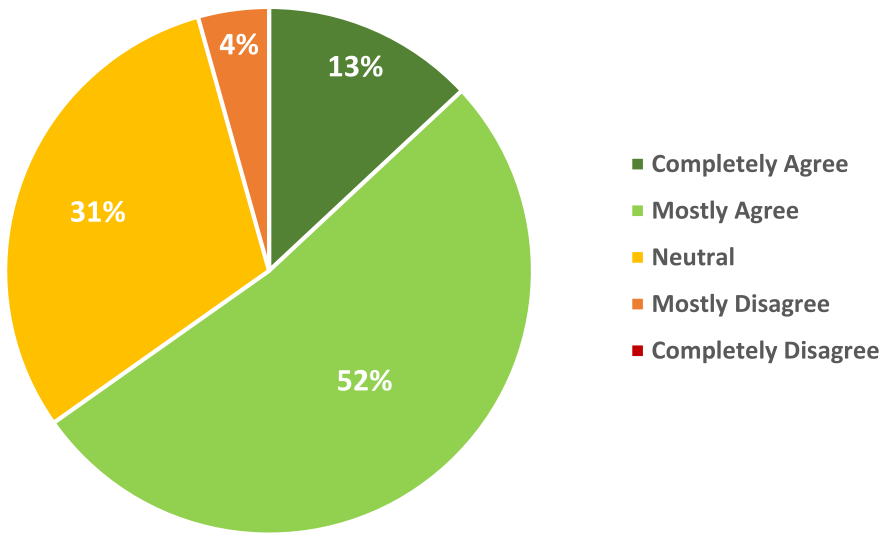
A key technical characteristic for storage assets, (specifically battery storage systems), is the amount of stored energy that can be drawn per operational cycle.

With regards to battery storage systems, this is referred to as Depth of Discharge (or DOD), and the level to which a battery system is discharged can heavily affect the number of charge-discharge cycles (i.e. cycle life) over time. The deeper the discharge level, the lower the cycle life (i.e. fewer number of cycles) a storage asset can achieve.

Depending on the nature of the storage assets and the business models they are operating under, some systems may look to discharge for longer (i.e. operate at a higher DOD), sacrificing longer term cycle life to maximise short term revenue. This would most likely be for high-value, rapid response programmes that require frequent charge/discharge behaviour (such as Enhanced Frequency Response).

For the purposes of modelling we have assumed a DOD of 80% (leaving 20% of the storage capacity in the battery on each cycle) for most storage assets. For storage assets specifically operating under the *Response Service* business model, the DOD could potentially be less, i.e. 30%-50%, to enable more regular, short-term charge/discharge, responding to e.g. dynamic frequency changes.

Question 13 - ***To what extent do you agree with a typical Depth of Discharge of 80%, for most battery storage assets currently being deployed?***



Question 14 - *How do you foresee this DOD changing over time?*

Questions 13 & 14 - summary of comments received:

Whilst the majority (65%) of respondents either completely or mostly agreed with the DOD values that we proposed, some respondents advised that they are seeing different values, with others answering neutrally due to not having sufficient technical knowledge to comment on this as a specific operational parameter.

The proposed values for DOD were arrived at with batteries as the prime technology and thus with battery preservation in mind. The feedback received regarding DOD suggested that the proposed values were conservative, and batteries are likely to be discharged deeper, beyond the 80% we have currently included in the modelling.

A number of reasons were given for this feedback. Firstly, as Lithium-Ion technology improves, batteries are becoming capable of reaching a deeper DOD without suffering an acute degradation in performance/cycle life. Although some degradation is present when batteries are run at 100% DOD, the economic benefit of the extra capacity tends to outweigh the lost income resulting from battery degradation. This is perhaps a function of short-term contracts/markets that these batteries are currently targeting in the 'wave 1' of storage deployment we discuss on Page 13 of this paper.

Another consideration that was raised, was those manufacturers whose batteries are not designed to achieve a 100% DOD, this is often factored into the quoted capacity of the storage asset and therefore needn't be accounted for additionally in the modelling.

Comments received also suggested that the market is likely to diversify to become less dominated by Lithium-Ion batteries, with other technologies on the horizon (e.g. Flow batteries and others discussed in Question 2), that suffer from less/no DOD-related degradation in performance.

As a result of the consultation feedback we will be adjusting our assumptions around DOD values now and out to 2030 in its network modelling of storage.

5 – Consultation Section 3 Results: Storage Asset Operating Modes

Understanding the Operation of Storage Assets

As part of our modelling with Regen, WPD are using the term 'operating mode' to describe a generic or typical mode of operation. An operating mode will profile a storage system's 'charge' and 'discharge' behaviour, over a 24-hour period.

It is important for WPD to understand the operating modes of storage systems, on a daily and seasonal basis. For other distributed generation, such as solar PV and onshore wind, there are known generation profiles across given days and times of the year based predominantly on known weather patterns. For storage however, the nature of demand (charge up) and generation (discharge) is less predictable and predominantly driven by other market factors such as:

- Price signals
- Generation and demand profiles
- Network events (*i.e. Capacity Market or STOR events etc.*)
- Network costs (*i.e. Triads, Duos-Red band charges etc.)*
- Contracted services (*i.e. frequency response, DSR etc.*)

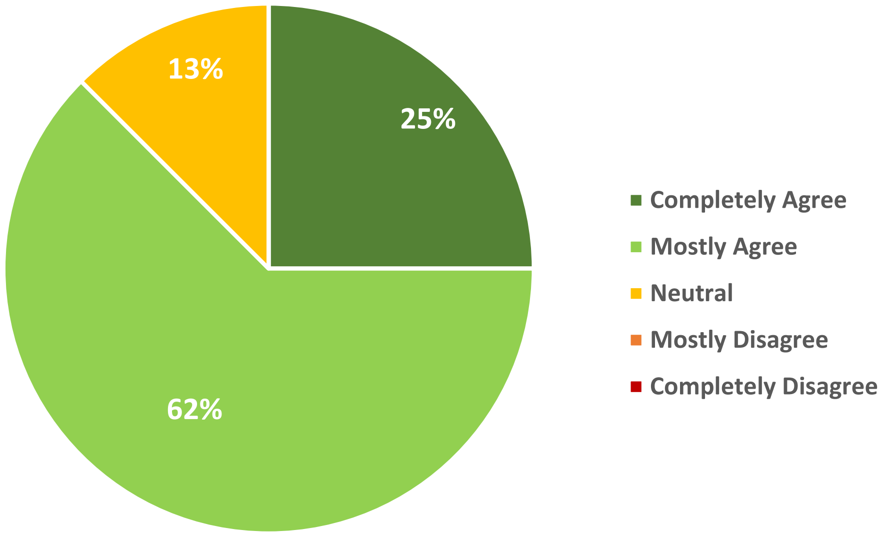
Representative Days

As part of the analysis of the aggregated impact of storage systems on the network, WPD have identified a number of representative days, three of which are used to define how each of the class of storage asset may operate differently at certain times of the year. The three chosen representative days are:

- **A winter peak demand day** - high demand and low levels of DG
- **A summer 'max generation' day** - low demand with high levels of DG
- **A typical spring/autumn day** - when demand and generation are average

By using these representative days, WPD are not trying to model every possible scenario, but capturing the aggregated effect on typical days of significant generation and demand that might drive specific storage operating modes, that would have a significant effect on the network.

Question 15 - ***To what extent do you agree with these 3 Representative Days, as a reflection of seasonal variation in operating behaviour of storage assets?***



Summary of comments received:

There was a significant level of agreement from respondents with the representative days themselves and the associated approach to assessing the daily and seasonal operating profiles of energy storage assets, with 87% either completely or mostly in agreement.

It was suggested that these representative days could be improved upon to enhance the accuracy of the modelling, proposing a separate/specific 'Max Solar Day' (rather than just a summertime max generation day), as well as the potential to factor in other events or additional days into the modelling.

WPD will continue to review these as key representative days and adjust our modelling accordingly.

Operating modes

We have defined 9 key operating modes, as below. It should be noted that these modes have been chosen as typical/generic modes and do not account for every possible variation.

i) Network Auxiliary Services - Operating under direct contracted response services such as frequency response. This mode is for battery systems that are dedicated to being available for these response programmes 24hrs a day.

ii) Network Auxiliary Services and Network Peak – Similar to mode i), but reserving a small window of operation (2-4hrs) to discharge in peak network charge and high commodity price periods.

iii) Balancing Service Standby - Operating mode reflecting operation under balancing service contracts, effectively operating to be available for STOR, Fast Reserve, Capacity Market etc.

iv) Balancing Service and Network Peak - Operating under balancing services contracts as above, but also carving out a window of operation to discharge during peak network charge and high commodity price periods.

v) Network Peak Charge Avoider - A mode of operation designed predominantly for behind the meter classes of project, whereby a storage system has been implemented to supply a demand load during network peak charges. Storage system charging is during lowest price periods.

vi) Cost Sensitive Self-Use - A mode where a demand user with generation is using storage to increase self-consumption of on-site generation, but weighted towards high commodity/delivery charge periods. This could currently be a commercial and industrial (C&I) user with generation, subject to cost sensitivity or smaller users with Time of use Tariffs.

vii) Maximise Self-Use - A mode where a demand user with generation is using storage to maximise self-usage of on-site generation, but is not sensitive to high/low price thresholds (i.e. domestic solar with a flat electricity import tariff). Charging when solar is generating, discharge when energy is needed.

viii) Generation Time and Price Shift – Using energy storage co-located with generation to time shift energy from a low to a higher price period.

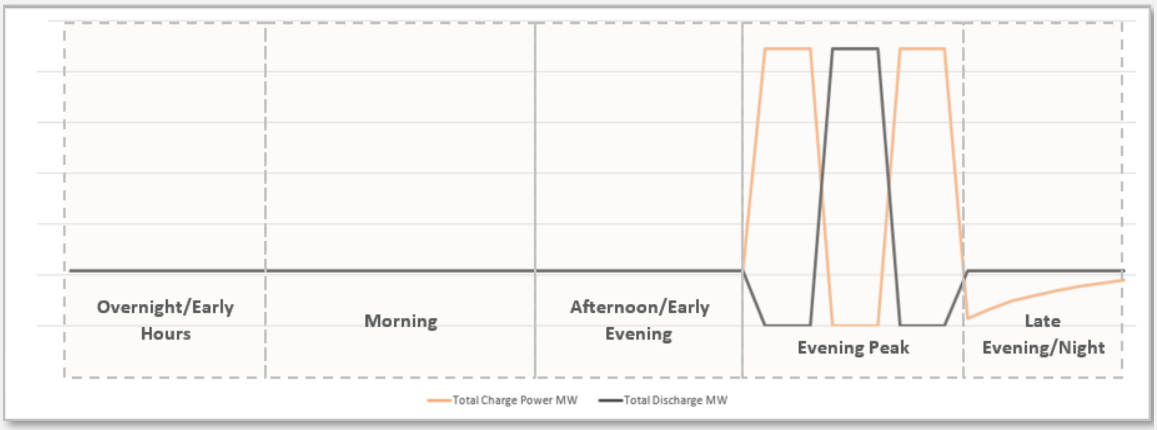
ix) Generation Peak Shaving – Using energy storage co-located with generation, but diverting a proportion of the generation into storage, so as to bypass grid export constraints. Likely to also discharge during high price periods.

Daily Operating Mode Profiles

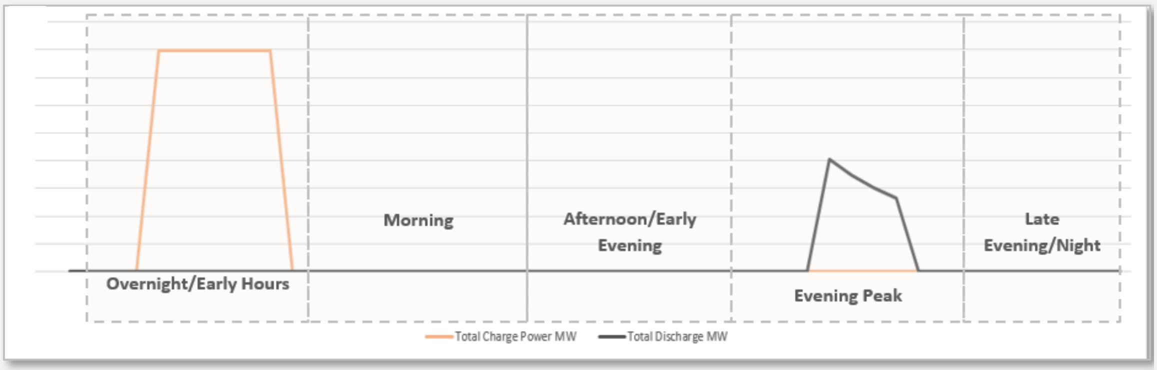
From the shortlist of 9 generic operating modes we have developed, we have generated indicative daily profiles of each operating mode. These are graphed visualisations and value profiles of daily energy charge/discharge trends, for a selection of the operating modes we have identified.

Please see three examples below for operating modes **ii)**, **v)** and **ix)**:

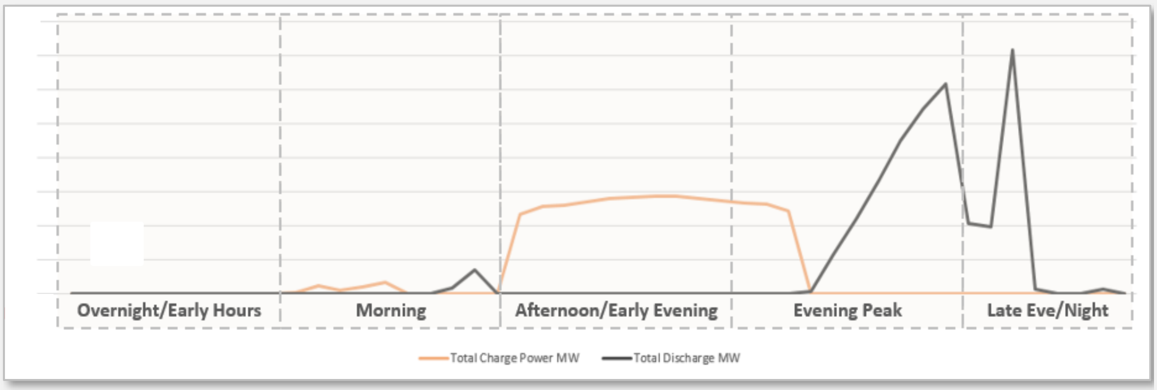
<u>Example 1</u>: Operating Mode ii) Network Auxiliary Services + Network Peak



<u>Example 2</u>: Operating Mode v) Network Peak Charge Avoider



<u>Example 3</u>: Operating Mode ix) Generation Peak Shaving (Solar PV)



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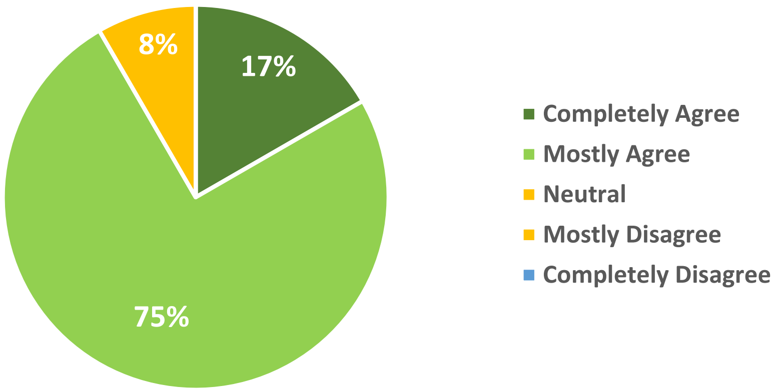
Question 16 - ***To what extent do you agree with the nine generic operating modes we have identified on page 28, and their operating behaviour?***



Summary comments received:

The identification of the 9 generic operating modes shown has been recognised by the respondents as a firm reflection of the range of operating behaviour of storage assets, with 92% of respondents either completely or mostly in agreement.

Some comments flagged up that the effect of the Capacity Market on the operating modes was unclear, as well as the evolving nature of the procurement of balancing services by the System Operator and potentially Distribution System Operator (such as WPD) in the future, may change some of the operating modes proposed. WPD is in agreement with this analysis, especially when referencing the direction of balancing services in National Grid's recent publication *System Needs and Products Strategy,* available at: www2.nationalgrid.com/UK/Services/Balancing-services/Future-of-balancing-services/

This shows a streamlining of balancing programmes and a finite volume of flexible capacity required in the immediate future.

Question 17 - ***Are there any generic operating modes we have not included?*** *Please could you provide some details*

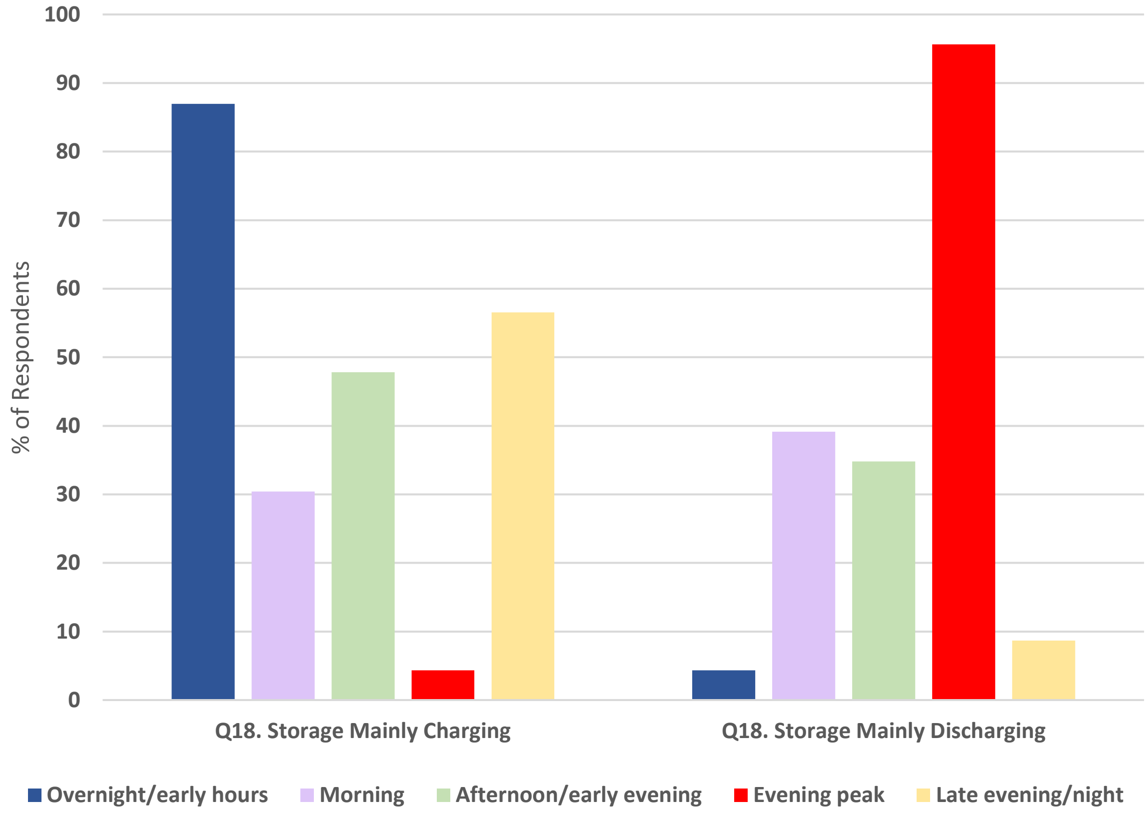
Summary of comments received:

Although the generic operating modes proposed were met with broad approval, a number of less generic, potentially more bespoke operating modes were discussed, including:

- *Aggregated dynamic storage operation – such as 'virtual power plants'*
- *Vehicle-to-Grid operating modes*
- *Renewable energy smoothing (potentially subtly different to peak shaving)*
- *Energy trader operation*
- *Local supply/local trading operation*

As a result of these comments WPD has added "Energy Trader" as a business model and will continue to review generic operating modes and consider how these may need to evolve in our network modelling of storage operation.

Question 18 - *During which periods of the day do you believe storage assets will be predominantly charging (causing spikes in demand) and discharging (causing spikes in generation)?*



Comments:

Although the responses we received showed a wide range of answers for when storage would be charging and discharging, some clear themes can be identified from the aggregated answers provided.

87% of respondents indicated that energy storage devices will likely charge up during quieter periods on the network (overnight), with 57% of respondents suggesting that there will also be a likely charge up period in the late evening/overnight.

96% of respondents indicated that storage devices will be discharging during the evening peak (e.g. 5pm-7pm), with 39% of respondents suggesting another active discharge period could be in the morning.

For other periods of the day, the responses differ more with a large spread reflecting the number of operational drivers and other signals that direct storage assets to either charge up or discharge part or all of their stored energy capacity.

A point of interest from a number of respondents, was that charging from co-located intermittent generation will not result in demand spikes, and will occur when surplus generation is available on the network.

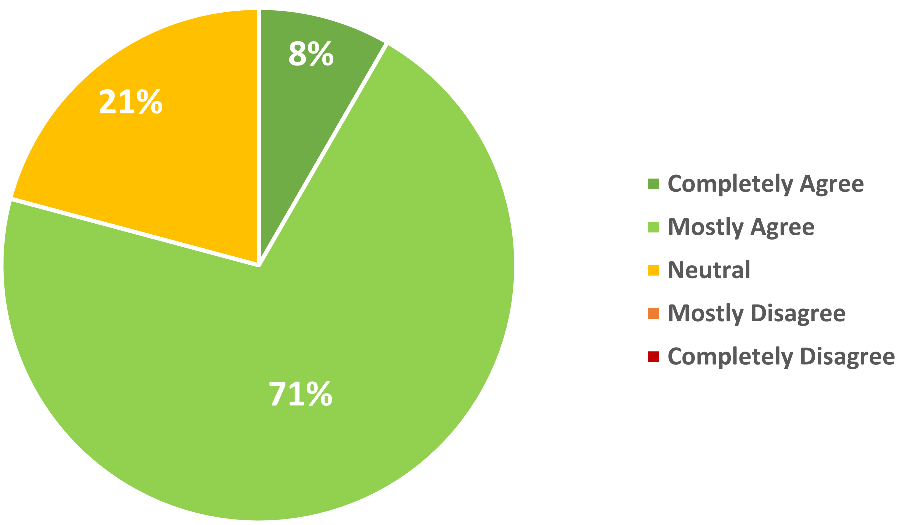
Question 19 - ***Which of the 9 generic operating modes we have identified do you believe will be operating on the 3 main Representative Days, that we have described on page 26?***

	Operating mode on Winter peak-day	Operating mode on Summer max gen day	Operating mode on Av. Spr/ Aut day
Network Auxiliary Services	78%	70%	68%
Network Auxiliary Services & Network Peak	91%	39%	42%
Balancing Services Standby	78%	39%	63%
Balancing Services and Network Peak	87%	30%	37%
Network Peak Charge Avoider	96%	35%	37%
Cost Sensitive Self-Use	78%	35%	58%
Maximisation of Self-Use	52%	78%	63%
Generation Time and Price Shift	70%	83%	74%
Generation Peak Shaving	52%	83%	53%

Legend:

- >85%
- 65%-85%
- 50%-65%
- 35%-50%
- <35%

Question 20 - ***To what extent do you agree with the three example daily operating mode profile graphs we have included on page 29?***



Comments:

79% of respondents either completely or mostly agreed with the daily operating mode profiles we showed on Page 29. There were some comments around the example we have for **ii) Network Auxiliary Services + Network Peak**, where some respondents believe storage assets are likely to be sitting at c.50% charge while delivering frequency response services. WPD will review this and adjust the operating mode profile threshold accordingly for auxiliary services modes.

6 – Summary of WPD follow-up action from consultation

Purpose of consultation

As we stated at the start of this paper, in undertaking this consultation, WPD was interested in understanding:

- *The potential scale of growth of energy storage within its distribution network*
- *The type of energy storage assets/projects that are likely to be deployed within its network*
- *The operating behaviour of storage assets, how they are likely to be used and their typical mode(s) of operation*

WPD will use the information we have received from the responses to this consultation, to inform its future network planning. Some specific areas we will be reviewing and amending in our modelling of the scale, specification and operation of storage assets are detailed below:

1. Storage Growth Scenarios

There is broad alignment of our growth scenarios for storage (see p.11) with the projections outlined by National Grid in their 2017 FES document (see p.8). We will continue review the scale of growth of storage capacity on our network and adjust our future network planning accordingly.

On our online Generation Capacity Register, which summarises the volume and number of storage connection applications we receive on a monthly basis, we have now included a new category of connections "***Enquired, but not yet offered***", alongside the existing categories of "***Offered, but not yet accepted***", "***Accepted, but not yet connected***" and "***Connected***".

We will use the feedback we have received on our growth scenarios in conjunction with the storage connection applications we continue to receive, to review the future projections of growth of storage capacity in our licence areas.

2. Storage Business Models

We have added a sixth business model of **Energy Trader** into our modelling for storage, which references the potential for generators using storage or energy suppliers as a means of arbitrage between low and high price periods, as well as the potential to bring storage into local supply models. Aggregation of smaller multiple storage assets together is a potentially key feature under this business model.

3. Storage Power and Energy Ratios

In the modelling of storage asset classes, we will be adjusting some of the power and energy ratio values, to reflect the feedback we have received. A summary of the changes to the relevant ratios in our modelling can be seen in Fig.12.

Business model	Storage Power [MW]	Storage Energy [MWh]		Generation Capacity [MW]	Peak Power Demand [MW]
		Now-2020	By 2030		
1. Response service	1	1	2	--	--
2. Reserve service	1	3	4	--	--
3. Commercial & Industrial	1	3	6	--	1
4. Domestic & Community	1	2	3	1	0.5
5a Generation Co-Location Solar	1	3	4	1	--
5b Generation Co-Location Wind	1	6	8	2	--

Figure 12 – Revised table of assumed Power and Energy Ratios

4. Storage Depth of Discharge (DOD)

In the modelling of storage asset operation, we will be increasing the DOD value over time from 80-95%, so as to reflect the feedback we have received around storage assets being cycled deeper into their full charged capacities, so as to maximise short-term benefits, as well as the points raised about known limitation of DOD being factored into declared capacity ratings of storage assets and technology improvements into the future.

5. Storage Generic Operating Modes

Based on feedback we received around the likelihood of 'stacking' revenues across all business models rather than focussing purely on one income stream or core operation, we have re-apportioned some of the capacity we have modelled under the 24-hour operating modes, as follows:

Reduce Allocation of Capacity	Increase Allocation of Capacity
i) Network Auxiliary Services (only) **iii) Reserve Services** (only)	**ii) Network Auxiliary Services & Network Peak** **iv) Reserve Services and Network Peak** **vi) Cost Sensitive Self-Use**

7 – Next steps

This consultation

We would like to again thank everyone who took the time to respond to this consultation around energy storage growth scenarios and operating modes. The responses have provided important insight into the current challenges and potential future scenarios of the storage market. Specific actions taken as a result of this feedback can be seen in the previous section – 'Summary of WPD follow-up action from consultation'.

We are continuing to develop our understanding of the storage market and the service requirements of customers that wish to operate storage assets connected to the network. The information and feedback we have received from this consultation has enabled us to refine the storage elements of our strategic network modelling and will be used to inform our next sub transmission study for the West Midlands area.

Government and Regulatory Drivers

On the 24th July, BEIS and Ofgem published their strategy energy document *Upgrading Our Energy System – Smart Systems & Flexibility Plan*:

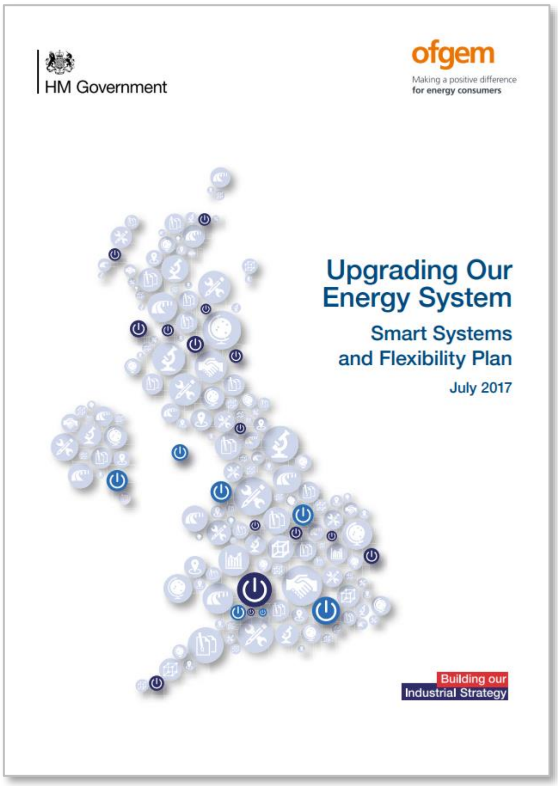


Figure 13 – BEIS & Ofgem 'Smart Systems and Flexibility Plan' (July 2017)
https://www.ofgem.gov.uk/system/files/docs/2017/07/upgrading_our_energy_system_-_smart_systems_and_flexibility_plan.pdf

Storage features heavily in this document as a key smart & flexible energy technology, with a series of guiding principles being proposed and a number of actions outlined to remove the barriers to a smart and flexible system.

An overview of some of the guiding principles that were outlined, are as follows:

i) To improve competition in markets to allow storage (and other flexibility services such as efficiency and interconnectors) to compete fairly in the market.
ii) To accurately reward the value of an asset and how it can support the energy system, including the allowance of the value of stacking benefits (which is very pertinent to storage assets).
iii) To increase the transparency of market signals, so as to provide both buyers and sellers with the information they need to build business cases.
iv) To encourage innovation in technology and enhancement of supporting processes, transaction procedures and supporting infrastructure.
v) Collaboration between all parts of the industry is key, with Distribution Network Operators (DNOs) being identified as a key party, alongside the System Operator, generators, suppliers, technology companies and aggregators as well as local authorities, community energy groups and Local Enterprise Partnerships.

There are a number of areas where BEIS and Ofgem have highlighted that DNOs have a key role to play, namely:

"*Network companies should enable an energy system that supports the market for the development and implementation of storage, but DNOs should not own or operate storage themselves. Those DNOs who already own storage will also be subject to new reporting requirements*."

The transition of DNOs to Distribution System Operators (DSOs) is a key part of the evolution of the energy system WPD has recently published its *DSO Transition Strategy* document, seeking views on a proposed £125m investment strategy to successfully transition to this new DSO role.

Figure 14 – WPD DSO Transition Strategy, published July 2017
https://www.westernpower.co.uk/docs/About-us/Our-business/Our-network/Strategic-network-investment/DSO-Strategy/DSO-Transition-Strategy.aspx

ENA 'Open Networks' Project

The knowledge and understanding developed during this consultation will feed into the Open Networks Project (ONP), run by the Energy Networks Association (ENA). This is a broad, evidenced based review of the energy network that will inform implementation of positive change with regard to process and project efficiency, safety, and policy structure. The project was launched in January 2017, and is currently in its initial review stage, comprising an identification of the aspects of the network in need of change, by engaging in a complete assessment of the grid.

It is hoped that this project will lay the foundations for the inevitable transition to a smart energy grid, including the DNO-DSO transition, and the deployment of smart metering and appliances in domestic households. The ambitious nature of this project calls for robust engagement on a number of fronts, including various NGOs, trade associations, academics, BEIS, the SO, and, of course, the seven DNOs.

Open Networks Project Overview

The following schematic summarises the Open Networks Project, and illustrates the relationship between relevant issues and project work streams.

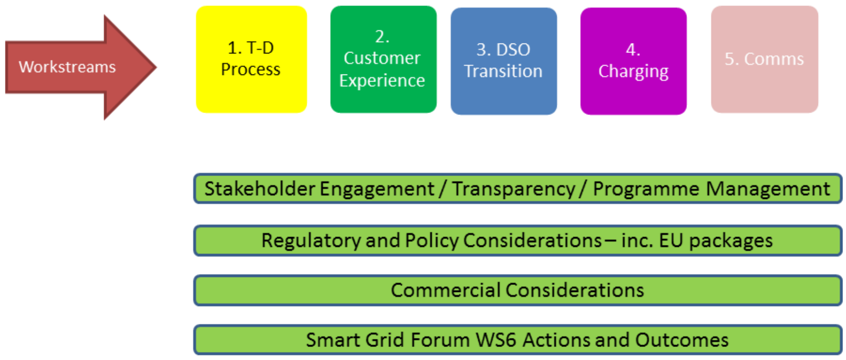


Figure 15: ENA ONP cross cutting issues
http://www.energynetworks.org/electricity/futures/open-networks-project/open-networks-project-overview/

The following explanation accompanies figure 15 on the ONP webpage: "The objectives of the Open Networks Project for the first phase of work in 2017 are to:

1. Develop improved ***T-D processes*** around connections, planning, shared TSO/DSO services and operation
2. Assess the gaps between the ***experience our customers*** currently receive and what they would like, and identify any further changes to close the gaps within the context of a 'level playing field' and common T & D approach
3. Develop a more detailed view of the required transition from ***DNO to DSO*** including the impacts on existing organisation capability
4. Consider the ***charging*** requirements of enduring electricity transmission/distribution systems"

This consultation therefore forms part of WPD commitment to the ONP, and the wider energy transformation.

Guiding Principles for Storage

As a result of this consultation and the drivers from BEIS and Ofgem outlined above, WPD have identified some key areas to be investigated and progressed, to ensure the benefits of energy storage can be realised on its network.

i) Delivering quicker, more efficient connections

Building on the guidance to connecting storage we have issued to date, we wish to streamline the process for reviewing and approving storage connections. Understanding the nature of the operation of storage assets will enable WPD to better understand their impact on our network and thus in-turn reduce the time to process and issue a connection offer where possible. WPD will continue to review the connection process for storage assets and would welcome any feedback on out '*Guidance on the connection of energy storage devices to Western Power Distribution's Distribution System*' document that we launched in June 2017.

ii) Facilitation of the stacking of services and associated revenues

WPD understands that the business case for some storage assets is reliant upon the ability to leverage more than one service and thus source of income/revenue stream. This in turn may require storage assets to operate differently across given days and different seasons, as well as potentially responding to specific network events and/or price signals.

WPD will therefore continue to assess how we can support the connection requirements of storage assets that are likely to operate flexibly and reactively.

iii) Prioritising storage to connect, where it will alleviate constraints

WPD recognises that the way electricity is generated, distributed and consumed is changing. Our role as DSO will involve more active management of the system, to further accommodate the significant volume of distributed generation required for a low carbon transition. With certain operating profiles, we see storage and other non-traditional forms of flexibility situated within constrained networks as being able to help benefit the network.

WPD will consider how to prioritise the connection of storage assets, where there is evidence that it will alleviate constraints on the network.

Contact Information

WPD

If you have any questions around this consultation or the contents of this report, please contact WPD on the below details:

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Regen

WPD have worked with Regen on developing the thinking, analysis and modelling of storage that formed the basis of this consultation. If you have any questions on the approach to the modelling of storage growth, business models for investment or operating behaviour, please contact Regen on the below details:

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