Department for Business, Energy & Industrial Strategy

ofgem Making a positive difference for energy consumers

Transitioning to a net zero energy system

Smart Systems and Flexibility Plan 2021

July 2021

Executive Summary

Rapid, exciting, and fundamental change is happening across our energy system. We are on the cusp of a global Green Industrial Revolution.

In April, the UK government announced a world-leading climate change target (the sixth Carbon Budget) to reduce emissions by 78% by 2035 compared to 1990 levels, on a pathway to net zero greenhouse emissions by 2050. Our success in achieving this will rest on a decisive shift away from unabated fossil fuels to using clean energy. It will require harnessing energy from low carbon sources such as the sun and wind, to power our homes, businesses and vehicles. The government has already set out ambitious goals, including building 40GW of offshore wind by 2030, ending sales of petrol and diesel cars by 2030, and deploying 600,000 electric heat pumps per year by 2028 to replace fossil fuelled heating systems. All these technologies will need to be seamlessly integrated onto our energy system so that low carbon power is available in the right places and at the right times to meet our energy needs.

This Plan, a joint publication by the government and Ofgem, the energy regulator, sets out a vision, analysis and work programme for delivering a smart and flexible electricity system that will underpin our energy security and the transition to net zero. This system will need significant levels of flexibility and utilisation of smart technologies so that it can be almost entirely run on low carbon energy sources. Consumers will be able to shift demand to times of day when electricity is cheaper and more abundant. Variable renewable power will be stored for when it is needed. We will import power from other countries when they have more available electricity than we do – and vice versa. This flexibility will be facilitated by regulatory and market reform, investment in innovation, and system digitalisation. Each chapter of this Plan sets out a vision, and a series of actions, to deliver a smart and flexible energy system (for a full list of actions, see **Annex 1: Full list of actions**). Alongside this Plan, we have published the UK's first Energy Digitalisation Strategy, as digitalisation is an essential requirement for realising a smart and flexible energy system.

The transition to a smarter and more flexible energy system is an opportunity. It will be delivered by UK businesses and will benefit consumers across the country. It will reduce the costs of our system by up to £10bn a year by 2050, by reducing the amount of generation and network we need to build to meet peak demand. It will create jobs, perhaps 24,000 by 2050, and drive investment across the UK. The UK is a global leader in smart systems and there is significant export potential for the solutions that we will need to deploy at home. As nations confront the challenge of climate change, markets for new green products and services will spring up round the world. Taking action now will help position UK companies and our world class research base to seize the business opportunities which flow from it, creating jobs and wealth for our country.

We need to move quickly. It will be very difficult to achieve the deep power sector decarbonisation needed to achieve the sixth Carbon Budget without significantly higher levels of system flexibility. The need for flexibility will rapidly increase as variable renewable power replaces fossil fuel sources, and we electrify heat and transport. The illustrative scenarios in our analysis indicate the scale of deployment that could be needed. Around 30GW of total low carbon flexible capacity in 2030, and 60GW in 2050, may be needed to maintain energy security and cost-effectively integrate high levels of renewable generation. While these

scenarios are just examples of many possible pathways for the electricity system, we expect the requirement for low carbon flexibility to be significant in all decarbonisation pathways, with substantial increases in deployment needed from the 10GW of low carbon flexibility on the system today. If we do not achieve this, we risk having to build more fossil fuel generation instead, in order to maintain energy security in the 2030s.

This Plan has been developed in close co-ordination with the sector. Over the course of 2020 and early 2021, we carried out extensive stakeholder engagement to understand the barriers to a smart and flexible energy system, and we are extremely grateful for the levels of engagement we received from experts across the sector who generously gave their time and expertise, despite the difficulties faced due to COVID-19.

The **Introduction** explains what a smart energy system is, the benefits it will bring, and analysis on how much flexibility is required to meet our decarbonisation targets (this analysis is set out in greater detail in Appendix I). It also sets out our approach to driving flexibility, the scope of this plan, and includes actions on the cross-cutting areas of skills and innovation. Following the introduction we briefly consider **future thinking on the electricity market**, including areas beyond the scope of this Plan.

Chapter 1: Facilitating flexibility from consumers explores how to support consumers to provide flexibility to the system and reduce their energy bills: deployment and use of smart technologies, removing barriers to the provision of consumer flexibility services, appropriate regulation for flexibility service providers, protecting consumers in a smart energy system, and embedding cyber security. This chapter also sets out actions to drive flexibility in buildings and smart electric vehicles and considers how to facilitate local flexibility solutions.

Chapter 2: Removing barriers to flexibility on the grid: electricity storage and interconnection sets out how we will address policy and regulatory barriers facing electricity storage, in particular smaller and larger scale solutions. The chapter also explores the changes needed to support increased levels of interconnection capacity and how to facilitate efficient and flexible access to cross-border markets.

Chapter 3: Reforming markets to reward flexibility explores how electricity market arrangements can unlock the full benefits of flexibility and how we are driving forward improvements to these markets and signals. It considers national and local flexibility markets, the Contracts for Difference scheme, and the Capacity Market. This chapter also explores coordination between markets at all levels of the system and the carbon intensity of flexibility markets and services.

Chapter 4: Digitalising the system highlights the importance of data and digitalisation in managing the transition to a smarter and flexible energy system. More detail and a suite of actions can be found in the Energy Digitalisation Strategy which we are publishing alongside this Plan.

Chapter 5: Delivering this plan sets out how we will track progress towards delivering the actions in this Plan and explains how we will monitor flexibility with a robust and systematic monitoring framework (more detail on this is set out in Appendix II).

Annex 1 provides a full list of the actions set out across the document.

Appendix I: Electricity System Flexibility Modelling sets out our analysis of the impact of low carbon flexibility in a decarbonised electricity system. This assessment builds on the analysis published with the Energy White Paper.

Appendix II: Smart Systems and Flexibility Plan – Monitoring Framework is the first iteration of our smart monitoring report. It describes the data we have collected and our assessment of how flexibility is developing in the system. The initial report provides the baseline for future monitoring to be assessed against.

This Plan is an important part of the government's forthcoming Net Zero Strategy and Energy White Paper, and a core component of Ofgem's Forward Work Plan and future-facing work to enable the energy system transition. It is supported by the government's significant increase in public research and innovation spending, including on smart systems and storage technologies. It builds on the government and Ofgem's joint 2017 Smart Systems and Flexibility Plan and 2018 Progress Update.

This Plan represents the next phase in smart systems policy. It certainly won't be the last. We will continue to work closely with the energy sector and beyond, to identify barriers to a smart and flexible energy system, adapting our approach as necessary, and implementing new policies as appropriate.

Why this area is important

Currently, flexibility on the electricity grid primarily comes from fossil fuel generation. Over the next decade this will increasingly need to come from electricity storage, which shifts electricity in time, and interconnection which shifts electricity in location. Other sources of grid flexibility include dispatchable low carbon generation (such as biomass and – in the future – hydrogen) and intermittent low carbon generation (such as solar and wind)[48]. This chapter will primarily focus on removing existing barriers to flexibility provided by electricity storage and interconnection.

Electricity storage, simply put, stores electricity for when it is needed. It is essential to a net zero system as it can store electricity when it is abundant (e.g. when it is windy or sunny) for periods when it is scarce (e.g. when demand is higher). It can do this both to balance the system nationally, and to manage constraints in local areas. It can also provide specific services to help maintain the resilience and stability of the grid. The need for electricity storage will rise as we increase the volume of variable, non-dispatchable renewables on the system and increase peak demand through the electrification of heat and transport. It will be critical to maintaining energy security as we shift away from gas over the 2020s-30s.

There are a range of technologies that can provide electricity storage, each with characteristics that may be needed by a net zero system. Lithium-ion battery storage, which typically operates at durations of 30 minutes to 4 hours, has significantly reduced in cost – around 90% since 2010[49] – and can provide rapid response to changes in system needs. Lithium-ion is the most prevalent battery currently however other chemistries exist or are in development. Battery storage can be deployed on the grid, and also at a domestic and commercial scale enabling consumers to reduce their energy bills and support the integration of low carbon transport and heating. A further significant source of battery storage could be electric vehicles operating in two-way charging mode, known as vehicle-to-grid.[50]

Storage over longer periods of time, for example across days, weeks and months, can help to manage variation in generation and demand, such as extended periods of low wind or cold weather events. Such technologies are typically larger in size, and include pumped hydro storage, compressed air, liquid air, flow batteries, gravitational and the conversion of power to hydrogen and back to electricity. Long duration storage could help to support the wider decarbonisation of the energy system: reducing the amount of investment in generation and

[48] Intermittent renewables can provide flexibility when they are available. They are able to respond quickly to market signals, and can be combined with supercapacitors and batteries to provide ancillary services such as synthetic inertia and reactive power. The Electricity System Operator's Power Available project is facilitating this by providing better visibility of the response and reserve capabilities of over 90 wind generators, with work underway to expand to solar generators too.

[49] BloombergNEF (2020), https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh/

[50] National Grid Electricity System Operator Future Energy Scenarios 2020 describe that vehicle-to-grid technologies could offer up to 38GW of battery capacity from 5.5m vehicles in 2050. National Grid ESO (2020), FES 2020, https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2020-documents

network assets that would otherwise be needed, and optimising the output from renewables e.g. through reduced curtailment costs.

Electricity interconnection is the connection of neighbouring markets through large underground or underwater cables so that when there is an abundance of electricity in one market, it can be exported to another – and vice versa. It delivers lower costs for consumers, enhances security of supply, and supports the integration of low-carbon generation sources. It provides access to a diverse pool of generation allowing the import or export of cheaper electricity by responding to changes in market signals; it can provide a range of system services, such as black start; and it also helps to reduce the curtailment of renewable energy.[51] Interconnection will be critical in realising our offshore wind target of 40GW by 2030 whilst maintaining security of supply, as multi-purpose interconnectors can further facilitate the efficient integration of offshore windfarms more quickly and in a coordinated manner.[52]

What has been done so far

- Ofgem published a modified generation licence for storage which exempts facilities from payment of certain policy costs, provides a regulatory definition for storage, and provides regulatory clarity for facilities below 50MW.
- The government passed legislation to make it simpler for larger storage facilities to acquire planning permission.
- Ofgem approved a series of code modifications to end the double charging of certain network costs for storage, and the government clarified how storage can be exempt from the Climate Change Levy.
- The government launched the Smart Export Guarantee which incentivises co-location of storage with solar; Ofgem provided guidance on how to co-locate solar and storage under the Renewables Obligation and Feed-in-Tariff schemes.
- Ofgem introduced licence changes to clarify that network operators cannot own or operate storage.
- Several innovation projects were launched: £20m to support deployment of large-scale storage, £9m on energy storage cost reduction and £317m on the Faraday Battery Challenge.

[51] BEIS (2020), Impact of interconnectors on decarbonisation, https://www.gov.uk/government/publications/impact-of-interconnectors-on-decarbonisation
[52] Prime Minister's Office, 10 Downing Street, BEIS (2020), https://www.gov.uk/government/news/new-plans-to-make-uk-world-leader-in-green-energy

- The Energy Networks Association published queue management guidance for electricity distribution network connections[53] and networks operators set out a fast-track connections progress for storage.
- Government launched the Offshore Transmission Network Review and has engaged with industry and North Seas stakeholders on the future of multi-purpose interconnection.
- Ofgem launched the Interconnector Policy Review and has been engaging with stakeholders on whether there is a need for further GB interconnection capacity, and its approach to the regulation of future GB interconnection.
- The EU-UK Trade and Cooperation Agreement outlined the need for UK and EU Transmission System Operators to cooperate to develop technical procedures for new, efficient cross-border trading arrangements at all timeframes, including cross-border balancing, and to ensure the maximum level of capacity of electricity interconnectors is made available.
- The Electricity System Operator has held information exchange sessions relating to potential cross border participation in the Dynamic Containment market; a working group is currently developing a non-mandatory technical specification relating to Grid Forming and Virtual Synchronous Machine capability, including inertia; and, a consultation has been published on Reserve Product Reform.

Where are we now?

Today, there is around 4GW of electricity storage operational in Great Britain, made up of 3GW of pumped hydro storage and 1GW of newer lithium-ion battery storage that has been built since 2017.[54] There is currently 6GW of operational electricity interconnection, a 50% increase in capacity since 2018. There are strong and growing electricity storage and interconnector pipelines; nearly 10GW of storage (8GW of battery storage and 2GW of pumped hydro storage),[55] 3.8GW of interconnector projects currently under construction, and an additional 6.1GW of interconnection projects with an approved GB regulatory route under Ofgem's interconnector cap and floor regime.

Electricity storage technologies are deploying at different scales, from domestic batteries to larger grid-connected facilities, and the sector is providing a wide range of benefits to the

[53] ENA (2020), Open Networks Project Queue Management User Guide (v4), https://www.energynetworks.org/assets/images/ON20-WS2-P2%20Queue%20Management%20User%20Guide-PUBLISHED.23.12.20.pdf

[54] National Grid ESO (2020), FES 2020, https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2020-documents

[55] Renewable Energy Planning Database (March 2021), https://www.gov.uk/government/publications/renewable-energy-planning-database-monthly-extract

system. Storage is now participating across a number of markets, including local flexibility markets and the balancing mechanism, and is dominating frequency response markets. In addition, there are continuing developments in a range of novel storage technologies as they work towards commercialisation. We have concluded from our engagement with industry that whilst some regulatory barriers remain for grid connected battery storage, many of the most significant barriers relate to our energy markets (see the next chapter). However, there is still not a level playing field for storage at all scales, and key policy and regulatory barriers remain for specific types of storage, in particular smaller units in homes and businesses, and large scale and long duration storage.

For interconnectors, there are currently two routes for investment: a regulated route through Ofgem's 'cap and floor' regime,[56] or via a fully 'merchant route' where no support is provided. Further deployment of interconnection will help to position Great Britain as a potential future net exporter of green energy. Whilst there is the need to continue to support the development of further capacity, which includes removing barriers to the development of multi-purpose interconnectors, we also need to ensure the right tools and mechanisms are in place to fully realise the potential for interconnection to contribute to overall system flexibility. Interconnection can support a flexible system to rapidly respond to changes in demand and supply. However, without the appropriate frameworks in place to enable flexibility services, greater interconnection could result in system operability challenges. Even with the current level of interconnection, individual interconnectors are among the largest capacity assets on the system and can cause large system swings. Such issues are compounded by each interconnector operating to bespoke rules with the ESO. Additionally, there are several commercial and regulatory barriers to entry for interconnectors' participation in future ancillary services markets.

Case study: Vanadium Flow Batteries - Invinity Energy Systems

Invinity's vanadium flow batteries can help the transition from fossil fuels to low-carbon sources by delivering low-cost, low-carbon energy on demand, reliably, safely and economically. Flow batteries offer the potential for many hours of storage at low cost due to the fact that the storage medium (electrolyte) can be stored outside of the battery stack (unlike lithium-ion batteries). The volume of the electrolyte can be increased at relatively low cost. In 2018 Invinity's predecessor company, redT energy was supported by government innovation funding under the energy storage cost reduction competition.[57] As a result of the programme, Invinity has been able to reduce the total cost of its stack by 75% (on a £/kW basis).

[56] Ofgem (2014), Electricity interconnectors factsheet, https://www.ofgem.gov.uk/publications-and-updates/electricity-interconnectors-factsheet
[57] BEIS (2021), Guidance: funding for innovative smart energy systems, https://www.gov.uk/guidance/funding-for-innovative-smart-energy-systems#funding-for-energy-storage-cost-reduction-and-feasibility-studies

Invinity is in the process of rapidly scaling its production capacity in line with increasing global demand. Since the beginning of the year, Invinity has expanded its production facility in Bathgate, Scotland and developed new manufacturing processes to enable significantly faster production, whilst increasing the number of 'green jobs' at the site. Invinity's factory is currently producing stacks for use in several projects being delivered this year, both in the UK and further afield, including Oxford, Orkney, Perth (all UK) and Yadlamalka (Australia).

What we will do

All storage

The regulatory framework was not built with technologies such as electricity storage in mind. We have made significant progress in clarifying and amending the treatment of storage within the framework, improving confidence for developers and investors, however there are still some barriers remaining.

It is important that we ensure there is clarity over the treatment of storage within the regulatory framework and therefore the government remains committed to defining electricity storage as a distinct subset of generation in primary legislation, when parliamentary time allows. This will ensure continuity with the current approach yet allow flexibility for treating storage differently to other forms of generation where it is appropriate to do so. In addition, the government will amend key planning guidance documents to set out the need case for storage and reflect the legislative changes made in 2020. This will support the planning permission process for planners and developers.

We will ensure there is a level playing field between storage co-located with generation, and standalone storage. Currently there are barriers to deploying storage alongside generation projects supported under the Contracts for Difference (CfD) scheme. In principle, storage should be able to provide grid services and store power from CfD generators, providing the metering arrangements can distinguish between the two. As stated in the 2016 consultation on CfD contract changes, CfD payments would therefore be calculated on the metered volumes at the point of generation, rather than the point of sale of the electricity. We will work with the Low Carbon Contracts Company to produce guidance to clarify co-location requirements, to better facilitate the addition of storage to CfD projects including offshore developments and, if necessary, we will consult on changes to the CfD contract requirements.

Storage can help facilitate the integration of renewable generation on the system by acting as a source of demand to alleviate generation constraints, deferring or avoiding the need for costly network build. Ofgem is committed to considering how the charging regime should