Department for
Business, Energy
& Industrial Strategy

Appendix II: Smart Systems and Flexibility Plan Monitoring Framework

Monitoring flexibility for a net zero electricity system

July 2021

Any enquiries regarding this publication should be sent to us at: smartenergy@beis.gov.uk

Contents

Introduction and summary

In 2019 the government set a target for the UK to meet net zero carbon emissions by 2050. Our success in achieving net zero will rest on a decisive shift away from fossil fuels to using clean energy. This will require harnessing energy from low carbon sources such as the sun and wind, to power our homes, businesses and vehicles. To meet this challenge, the government has set out ambitious plans, 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. This means that significant volumes of additional generation and demand will be added to our electricity system over the next few decades. This generation will increasingly be variable, dependent on the time of day, season, and prevalent weather conditions. Electricity demand will increase as heat and transport are electrified - potentially doubling by 2050.[1] In order to cost-effectively achieve this transition, we will need a smart and flexible energy system, using technologies such as storage, smart heat pumps and flexible charging of electric vehicles, so that low carbon power is available in the right places and at the right times to meet our energy needs.

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.[2] Around 30GW of total flexible capacity in 2030, and 60GW in 2050, may be needed to cost-effectively integrate high levels of renewable generation and potentially greater variability in demand over the year and during the day. 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 flexibility on the system today.[3]

The government and Ofgem, the energy regulator, have just set out series of actions to reform the energy system in a new Smart Systems and Flexibility Plan.[4] These actions are based on our current understanding of markets, technologies and consumer behaviour. However, the energy system is constantly evolving, new markets for flexibility are developing, new technologies are entering the markets, and consumers will have new choices to make in terms of how to interact with these technologies and markets.

The government and Ofgem’s approach to facilitating a smart and flexible energy system is largely about removing barriers, facilitating change, and spurring innovation to allow industry to

[1] BEIS (2020), Energy White Paper, https://www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future
[2] BEIS (2021), Smart Systems and Flexibility Plan, Appendix I: Electricity System Flexibility Modelling, https://www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021
[3] In 2020, there was around 10GW of flexibility on the system; 4GW of storage, 1GW of industrial and commercial DSR and 5GW of interconnection. Source: National Grid ESO (2020), Future Energy Scenarios 2020, https://www.nationalgrideso.com/future-energy/future-energy-scenarios/
[4] BEIS and Ofgem (2021), Smart Systems and Flexibility Plan, https://www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021

evolve to respond to the needs of our future energy system. This approach relies on markets and industry working effectively once the identified barriers have been removed. We will monitor changes in the market to track how technologies and competition are developing. This enables us to assess if system flexibility is increasing fast enough to meet our ambitions, and whether the market-led approach remains fit for purpose or further measures are needed.

This document is the first iteration of our monitoring framework, based on engagement with the sector during 2020, including a major workshop in May 2020.[5] The data collected in this report will be used as a baseline for future monitoring. We recognise that this is the first step to an effective monitoring strategy. Our indicators will need to adapt to the changing landscape, new markets for flexibility will emerge and new data will become available. Stakeholders are best positioned to identify market barriers and suggest key indicators. We will work closely with stakeholders to understand the areas that are important to consumers and industry and reflect these in our monitoring strategy.

Our approach

Our monitoring framework provides a systematic approach for identifying the outcomes we expect the new Smart Systems and Flexibility Plan (‘the Plan’) to deliver and selecting monitoring indicators to measure progress. We undertook a logic mapping exercise to identify the causal links between the actions in the Plan and the intended outcomes. A logic map provides a visual representation of the key steps required for a set of activities to lead to a specific set of objectives. It is also a tool for articulating the underlying assumptions of how changes will occur and the external factors which will also influence outcomes.

The Plan sets out a series of actions that are needed to enable a smarter and more flexible system. The impacts from many of these actions are overlapping and complex; multiple actions will contribute to a single outcome. There are also factors outside of direct policy control that will affect flexibility outcomes (e.g. falling technology costs, price volatility). We therefore do not consider it appropriate to track separate indicators for every policy action, and it is not possible to robustly attribute changes in outcomes to individual policy interventions.

To overcome this challenge, we have chosen a ‘**market monitoring**’ approach. We have identified a set of key outcomes that we expect multiple actions in the Plan to contribute towards. At a high level, our chosen outcomes are the deployment of flexible technologies and the performance of these technologies in markets. We expect that these outcomes will demonstrate the overall progress of flexibility in the electricity system. Greater deployment and participation of flexible technologies will be a direct sign that the electricity system is becoming more flexible and will be better able to cost-effectively integrate increased penetration of renewable generation and increased demand from transport and heat electrification. The aim is

[5] We held on online session with over 50 participants, including representation from academics, trade associations, suppliers, and generators. The workshop sought feedback in 3 areas: the effectiveness of the overall monitoring strategy, the proposed set of indicators, and publication to monitoring data. The feedback from participants was crucial in developing the first iteration of the monitoring framework.

to provide a holistic assessment of the progress of flexible technologies, to be able to understand if policy outcomes are on track to be met.

We have selected monitoring indicators that best measure the change in these outcomes. Our chosen indicators, and the rationale for selecting them, is set out in the next sections. For this first iteration of the monitoring report, we have only selected publicly available data. This provides a starting point for monitoring, but from this exercise we recognise that existing public data does not capture all the information that will be needed to track the progress of flexibility going forward. We have already identified a number of areas where further data would be valuable (see Next steps section) and expect that stakeholders will have further ideas. Some data will already be collected but be unpublished, while other areas will require new data to be collected. Rather than summarising unpublished data in our monitoring framework, it would be preferable if these datasets were available to all stakeholders. We will use the monitoring framework as a tool for improving the accessibility of data by working with stakeholders to identify and publish new data where appropriate.

The Energy Data Taskforce set out in 2019 the importance of digitalising the system and provided a clear vision of enabling this transformation. In response to one of the Taskforce's recommendations, the government and Ofgem commissioned the Energy Systems Catapult to develop Energy Data Best Practice guidance, a set of principles to help organisations to standardise and share their data. We will ensure these principles are followed as we work with stakeholders to improve existing data and open up new datasets. The Energy Digitalisation Strategy published alongside the Plan describes the progress we have made against the recommendations of the Taskforce and sets out new actions to further modernise the energy system through digitalisation.

Our monitoring framework needs to collect data over a sufficient period of time to ensure short-term fluctuations are not misinterpreted as longer-term trends, while being frequent enough to capture new developments as early as possible. We expect that annual data collation will be appropriate to capture the high-level trends in our indicators and will be sufficient to provide the holistic assessment of the progress of flexible technologies. However, this approach does not prevent us from more frequent data collection where appropriate, such as markets with fast moving developments or where stakeholders raise concerns.

How will monitoring data be used?

Monitoring data will be a consistent and timely source of evidence. It will form part of our evidence base, complemented by wider information gathering such as stakeholder feedback and system modelling. The monitoring will be used to understand high-level trends, to reassure that progress is as expected or highlight areas where more detailed analysis may be needed. Where indicators show that progress has been limited or that markets are not developing as expected, this will warrant further investigation to identify potential challenges. Ultimately monitoring evidence will be used to inform future policy changes and to identify priorities for unblocking remaining barriers.

Monitoring indicators

Table 1 sets out the monitoring indicators. The table also includes the mid-2020s vision for each of the Chapters of the Plan; this provides qualitative overview of the key outcomes that are essential to the delivery of that part of the Plan. We have chosen a set of indicators that broadly correspond to the Chapters in the Plan, and best capture the high-level outcomes described in the mid-2020 vision. At this stage, we have not developed specific indicators for the more detailed outcomes included with the Plan's list of actions.[6] Future iterations of the monitoring strategy will look link indicators to more granular outcomes where appropriate.

The indicators cover the capacity of different flexible technologies that are available on the system, including the rollout of domestic technologies such as smart meters and electric vehicles, and the performance of these technologies across different markets. We have highlighted some areas where data is not currently available, and therefore future iterations of the monitoring framework will look to gather additional evidence.

[6] See Annex 1: Full list of actions, BEIS and Ofgem (2021), Smart Systems and Flexibility Plan, https://www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021

Table 1: Monitoring indicators

Chapter of the Plan, and mid-2020s vision	Indicators	Rationale
Facilitating flexibility from consumers In the mid-2020s consumers of all sizes will be able to provide flexibility to the system, supported by the right infrastructure and regulatory framework. The market for flexibility from large consumers will have matured, with increased and sustained participation from a wide range of industrial, commercial, and public sector consumers. At the smaller scale, we will have reached market-wide rollout of smart meters to domestic and smaller non-domestic consumers across Great Britain. Consumers will be able to choose from a greater choice of innovative products like smart tariffs, as half-hourly settlement is implemented. Consumers will have access to a wide range of interoperable and secure smart appliances, and many will be rewarded for participating in demand side response. With rapidly rising numbers of electric vehicles, drivers will choose to smart charge because it is convenient and economical. Vehicle-to-grid technology (V2G) will be close to becoming a commercial reality for fleet operators. Smart technologies will be incorporated across the government's energy efficiency, heat, and fuel poverty policies. Consumers of all kinds (including those on low income and in vulnerable circumstances) will have the opportunity to choose and benefit from smart energy products and services, while those that do not participate will still receive fair and affordable outcomes.	- Proportion of domestic consumers with smart meters (% of total meters) - Ultra low emission vehicles (number of registrations) - Heat pumps deployment (number of domestic installations) - Industrial and commercial demand side response (GW available)	We expect the rollout of smart meters, and the deployment of domestic low carbon technologies to be leading indicators of consumer flexibility. As a higher proportion of consumers own electric vehicles or heat pumps, the opportunity for demand side flexibility increases. Future work could aim to gather information on the smart functionality of these technologies, enablers such as smart EV chargepoints and half-hourly settlement, as well as consumer behaviour such as take up of smart tariffs.
Removing barriers to flexibility on the grid By the mid-2020s we will have created a best-in-class regulatory framework for electricity storage at all scales; investors and developers will be confident in the framework, and this will trigger a marked increase in the deployment of storage. There will be a level playing field for domestic and small-scale storage. Customers will have confidence in the	- Storage deployment (GW) - Interconnection capacity (GW) - Storage pipeline (projects at different stages of development and time in pipeline)	The deployment of storage, as well as the size and duration of projects, provides an indicator of the amount of flexibility available on the system. The pipeline of projects is a leading indicator, showing the potential future deployment

benefits and framework for installing storage in their homes and businesses. Supported by government innovation funding, first-of-a-kind longer duration storage technologies will be built and provide services to the system. An increased capacity of interconnection will be facilitating efficient and flexible access to cross-border markets across all timescales. Ofgem's interconnector policy review will have concluded and any consequent changes to the current arrangements for new interconnectors will have been implemented to ensure the full range of potential benefits and impacts have been captured. As we work towards realising our 2030 ambition of at least 18GW of interconnector capacity, we will have a consistent and scalable approach to interconnector operability. BEIS will have also concluded the Offshore Transmission Network Review and recommendations will be implemented to facilitate multi-purpose interconnectors.	- Size of storage projects (proportion of projects in different MW size bands) - Duration of storage projects (proportion of projects in different duration bands – e.g. greater than 1-hour duration)	of assets, but also providing evidence on the number of projects that are not progressing to construction and operation. We mainly focus on battery projects, as this is the technology with most activity, but there are also pumped hydro storage projects in the pipeline and the potential for novel technologies to come forward. Future work should also look to capture new technologies as they enter the market, including novel energy storage technologies.
Reforming markets to reward flexibility By the mid-2020s, flexibility technologies of all types and sizes will have improved access to market signals for flexibility, enabling them to stack revenues across multiple sources of value where this enables whole system optimisation. Greater utilisation of flexibility resources reduces curtailment of intermittent low-carbon generation. Flexibility is widely used as an alternative to network build at both distribution and transmission levels, underpinned by transparent network investment decisions and competitive tendering. Implementation of new network access and charging arrangements incentivise more efficient and flexible network use. A step-change improvement in coordination between electricity distribution and transmission systems will ensure that balancing and network management maximise overall benefits to the whole electricity system. The Electricity System Operator (ESO) will have delivered	- Capacity market (GW of flexible technologies winning contracts and £/MW price achieved) - Balancing mechanism (MWh of bids and offers from flexible technologies, number of virtual lead parties) - Frequency response (MW of flexible technologies winning contracts and £/MW/h price achieved) - Distribution Network Operator flexibility markets (MW of tendered contracts, % of technologies winning contracts)	This range of indicators is chosen to cover the main markets in which we expect flexible technologies to be competing. The indicators will track the volume of different flexible technologies participating in each market, as well as information on the prices of key services. By looking across different markets we expect to be able to identify the different business models that technologies are following. There is a lot of change in this area. For example, new ancillary services markets are being developed. Future iterations of the monitoring report will need to capture the changes in markets and could include an

reforms to existing markets for flexibility services and the implementation of new markets will ensure that evolving system requirements are met to technically enable periods of zero carbon operation. We will have stronger investment signals for flexibility, which could include changes to the Capacity Market (CM) and Contracts for Difference (CfD) that ensure continued security of supply whilst driving investment in low-carbon flexibility. Carbon reporting and monitoring will be business as usual and the carbon impact of all flexibility markets will be understood to inform ongoing action to decarbonise the energy system.		assessment of carbon intensity across each market when this information is available.
Digitalising the system In the mid-2020s we will have standards and regulatory frameworks in place that ensure energy data collection and management meets best practice and data is treated as open and accessible by default while privacy protected. New digital services will make it easier for people to know what data exists and how they can gain access to it. These services will ensure datasets can interoperate with minimum time and effort for the user. The next steps for digitalising the energy system will have been identified, including what new data governance and market frameworks need to be developed to ensure data and consumer security while increasing market access and services.	We expect data and digitalisation actions be to enablers of many of the intended outcomes in the other areas of the plan. For this iteration of the monitoring framework, we have not selected specific indicators that relate to digitalisation. Future iterations of the framework could look to identify specific indicators for digitalisation, where outcomes are different to the other actions in the Plan. For example, indicators that could track the number of datasets that have been made available by different organisations and how often these datasets were requested by users. Further indicators could monitor the proportion of distributed assets (e.g. electric vehicles, heat pumps) that are registered in databases, or gather stakeholder feedback on their use of new instruments through the use of surveys.	

Findings from our first monitoring framework

The key findings from our initial monitoring exercise are as follows:

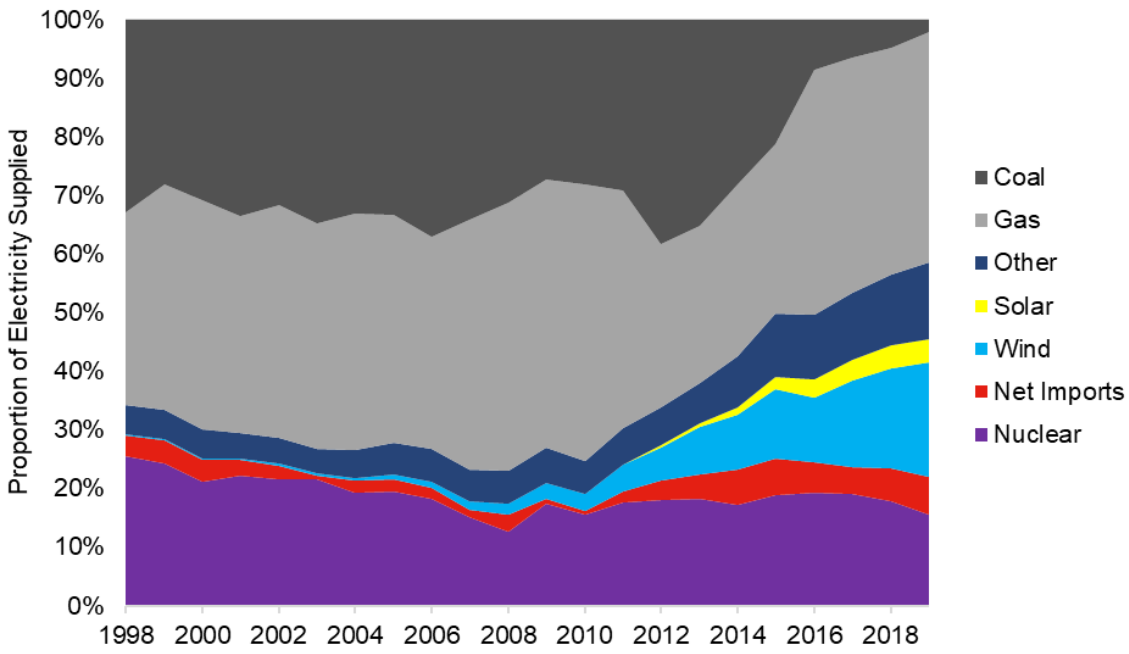
- **There is a clear and rising need for flexibility in the GB energy system.** An important driver of flexibility requirements, the share of renewables in the generation mix, is rising year on year. This will continue to increase with the ambition of 40GW of offshore wind by 2030. The electrification of heat and transport will also increase the demand on networks, growing the requirement of flexibility to avoid costly reinforcement. Most markets providing flexibility services—the balancing mechanism, ancillary services, Distribution Network Operator (DNO) flexibility markets—are growing, demonstrating the increasing need for flexibility.
- **Consumer flexibility is relatively nascent, but the roll-out of new technologies provides opportunities for growth**. Today, industrial and commercial consumers are already providing demand side flexibility. Participation from domestic and smaller non-domestic consumers remains at an early stage, but the on-going roll-out of smart meters and future implementation of market wide half hourly settlement are key enabling factors. The number of electric vehicles and heat pumps is increasing fast, indicating a growing potential for consumer flexibility.
- **The deployment of grid scale flexibility has increased, but greater progress will be needed as the electricity system decarbonises.** New deployments of batteries have slowed after an initial rush in 2018. The pipeline of storage projects, both pumped hydro and batteries, remains large, but there is uncertainty in the number of projects that will progress to construction and operation.
- **The participation of flexible technologies has increased but is inconsistent across markets. The coming years could see new markets and new business models develop.** Batteries now dominate frequency response markets and new products have increased the revenue opportunities in these markets. The share of bids from storage and demand side response (DSR) in the balancing mechanism remains very small, though DSR volumes are increasing. Distribution Network Owners' flexibility tenders are a nascent, but growing market. Evidence of a shift towards longer (2h) duration batteries winning capacity market contracts could suggest a change in business model. It is likely that merchant revenue in the balancing mechanism and wholesale market will become more important for new flexibility assets.

The following sections of this report set out the monitoring data we have collected in more detail and provide an overview of the next steps for developing this work.

Monitoring data

The GB generation mix and deployment of low carbon flexibility

Figure 1: Annual electricity generation by technology type

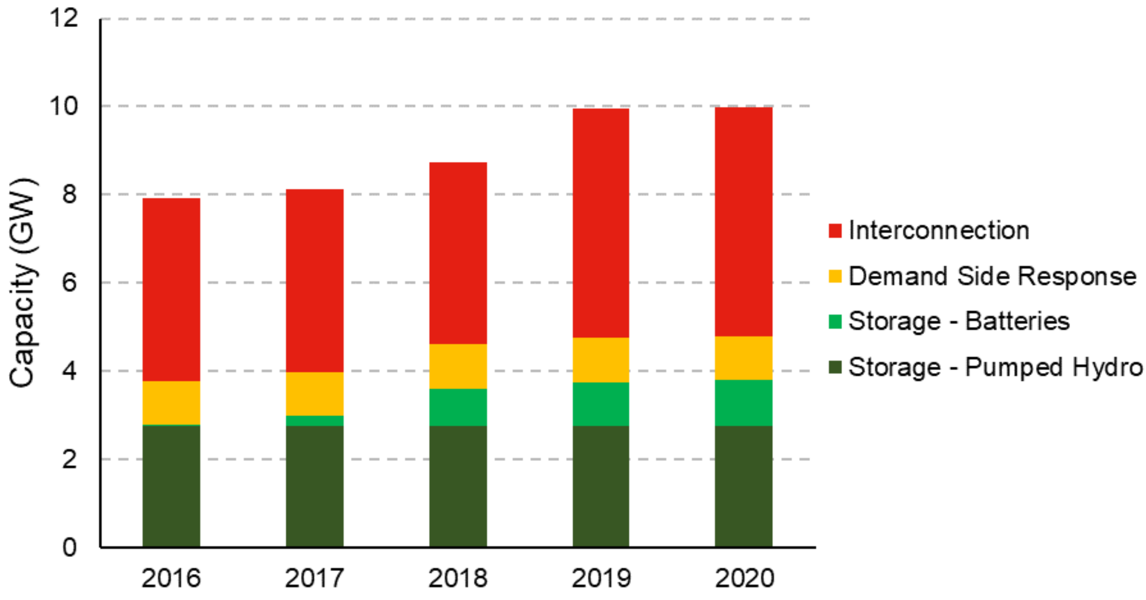


Source: BEIS Energy Trends, table 5.1
Note: "Other" includes oil, hydro, tidal, bioenergy and pumped hydro

The GB electricity generation mix is changing. In 2010, about 70% of generation came from coal and gas technology. In 2019 that had fallen to roughly 50%. The proportion of renewable generation has increased substantially in the last 10 years, to 30% by 2019. As a result, a smaller share of generation is made up of 'dispatchable' technologies (e.g. coal and gas) which can easily ramp up and down throughout the day to meet demand, and a greater share of generation is renewable technologies, which generate when weather conditions allow. This trend is likely to accelerate as we progress toward net zero emissions.

The electricity system needs to match generation and demand on a second-by-second basis to keep system frequency stable. System flexibility is the ability to adjust supply and demand to achieve that balance. Today, system flexibility is still predominately provided by gas generation. However, matching supply and demand in a future decarbonised power system will require low-carbon flexible technologies such as storing electricity until its needed or shifting demand to times when wind and solar are generating, and interconnection with other countries to avoid the inefficiency of having generating capacity which is only used a fraction of the time.

Figure 2: Deployment of low carbon flexibility



Source: National Grid Future Energy Scenarios, BEIS Renewable Energy Planning Database

Figure 2 shows the capacity of low carbon flexibility deployed on the system over the last 5 years. At the end of 2020 there were around 10GW of flexible capacity from 5GW of interconnection,[7] 1GW of demand side response from industrial and commercial consumers, and 4GW of storage made up 3GW of pumped hydro storage and 1GW of newer lithium-ion battery storage.

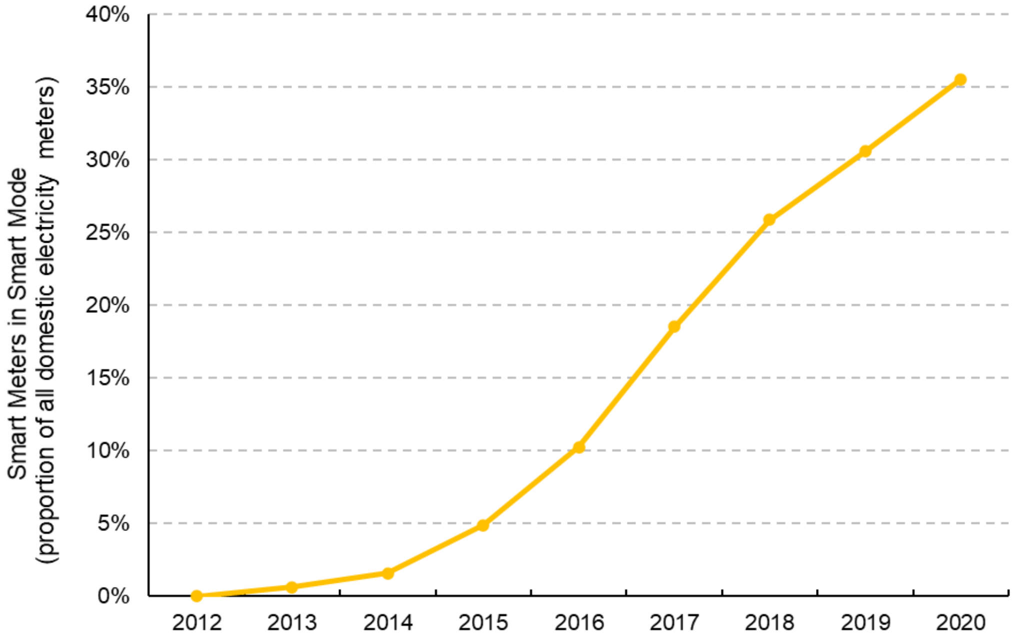
The capacity of interconnection and storage has increased over the last 5 years. In 2019, the BritNed interconnector was commissioned, adding a further 1GW capacity. In January 2021 the second electricity interconnector between the UK and France, IFA-2, began operating (not included in Figure 2). Lithium-ion battery storage has also started to be deployed on the system, with the vast majority of the existing 1GW of capacity being deployed since 2016.

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.[8] Around 30GW of total flexible capacity in 2030, and 60GW in 2050, may be needed. 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.

[7] Excludes the IFA-2 interconnector that was commissioned in January 2021.
[8] BEIS (2021), Smart Systems and Flexibility Plan, Appendix I: Electricity System Flexibility Modelling, https://www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021

Facilitating flexibility from consumers

Figure 3: Proportion of domestic smart electricity meters operating in smart mode, all suppliers



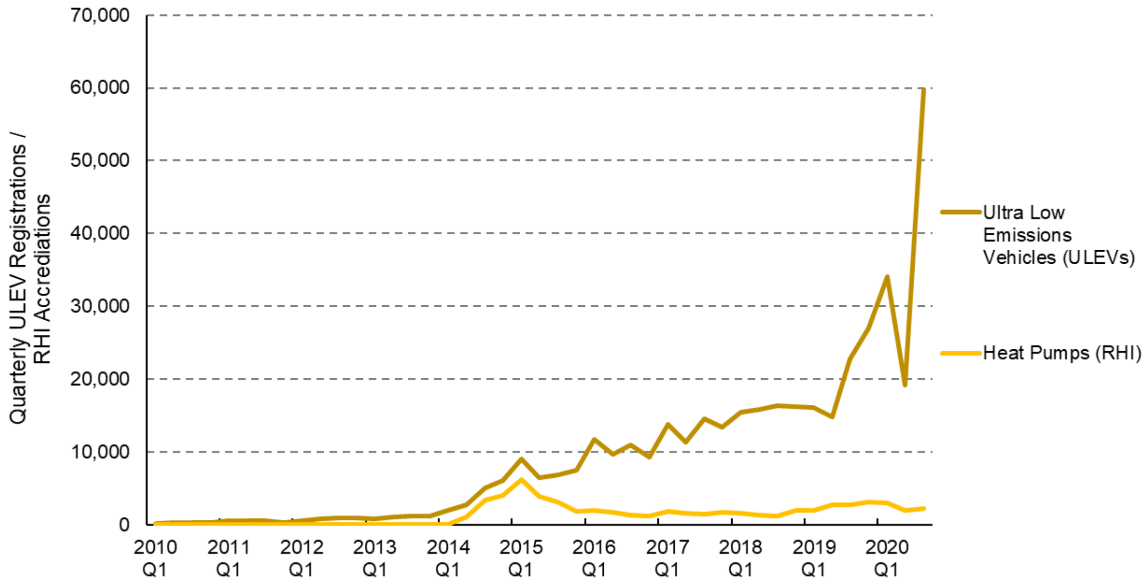
Source: BEIS, Smart Meters in Great Britain

We expect the rollout of smart meters, and the deployment of domestic low carbon technologies to be leading indicators of consumer flexibility. Smart meters support the transition to a low-carbon energy system by providing more granular consumption data to consumers, helping them take better control of their usage across multiple devices and engage with smart services offered by industry. Products such as smart 'time of use' tariffs incentivise consumers to save money by using energy away from peak times and enable technologies such as electric vehicles, heat pumps and smart appliances to be cost-effectively integrated with renewable energy sources.

The proportion of smart electricity meters has increased significantly since their introduction in 2012. At the end of 2020, around 36% of domestic electricity meters were smart meters in smart mode (see Figure 3). The continued rollout of smart meters, alongside reforms to introduce half hourly settlement,[9] will be an important factor to enable greater demand side flexibility in the future.

[9] Electricity suppliers are required to buy enough energy from generators to meet their consumers' needs in each half-hour period, and 'settlement' is the process for determining whether what they bought matched what their customers used. Most domestic and smaller non-domestic consumers are currently settled based on estimates of how much they have used in each half-hour period. However, the rollout of smart and advanced meters, which can record the amount of energy consumed in each half-hour period, means information about customers' actual consumption of electricity on a half-hourly basis can be used in settlement.

Figure 4: Quarterly ultra-low emissions vehicles (ULEVs) registrations and domestic renewable heat incentive (RHI) heat pump deployment



Source: BEIS Renewable heat incentive statistics; Department of Transport Vehicle licensing statistics

The rollout of electric vehicles and heat pumps will increase the demand for electricity, but their controllable load also provides an opportunity for demand side response. As part of the Prime Minister's Ten Point Plan for a Green Industrial Revolution, in November 2020 the Government announced its intention to end the sale of new petrol and diesel cars and vans in the UK from 2030 and deploying 600,000 electric heat pumps per year by 2028 to replace fossil fuelled heating systems.[10] As the deployment of low carbon technologies increases, it will be important that these technologies are able to use electricity at times where it is cheaper and cleaner, and to ensure the system as a whole can run at lowest cost by flattening demand peaks.

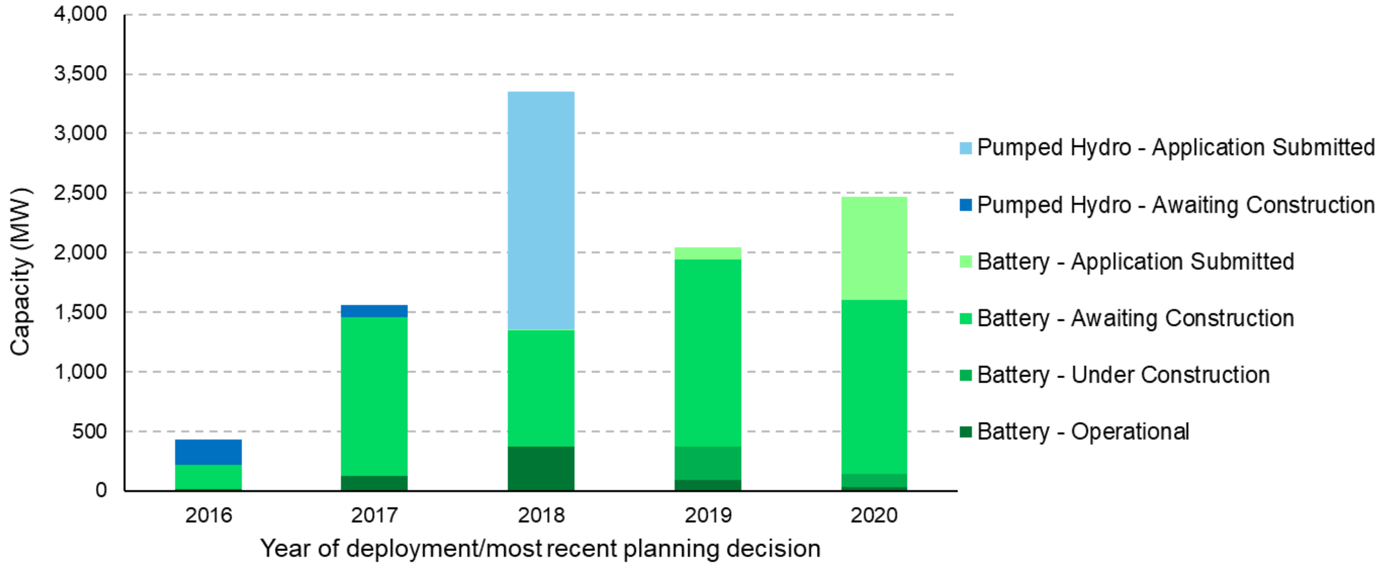
The number of Ultra Low Emission Vehicles (ULEVs) registrations has rapidly increased since 2012. There were around 80,000 new registrations in 2019, and around 115,000 in the first 3 quarters of 2020 (see Figure 4). Going forward it will also be important to capture data on the number of chargepoints installed alongside consumer charging behaviour.

The domestic renewable heat incentive (RHI) was introduced in Great Britain in April 2014 to encourage a switch to renewable heating systems in the domestic sector, while there are also a smaller number of heat pump accreditations on the non-domestic scheme. Since 2016 the number of heat pump accreditations (air source and ground source) has been broadly stable at around 2,000 per quarter. Historically, the RHI will have captured a sizable proportion of the market, but as the deployment of heat pumps increases, we will need a more complete data source that covers a number of subsidy schemes as well as installation that are not supported by subsidy. Data on thermal storage will also help identify the opportunity for flexible use of heat pumps.

[10] BEIS, Prime Minister's Office, 10 Downing Street (2020), The Ten Point Plan for a Green Industrial Revolution, https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution

Removing barriers to flexibility on the grid

Figure 5: Pipeline of storage projects in GB



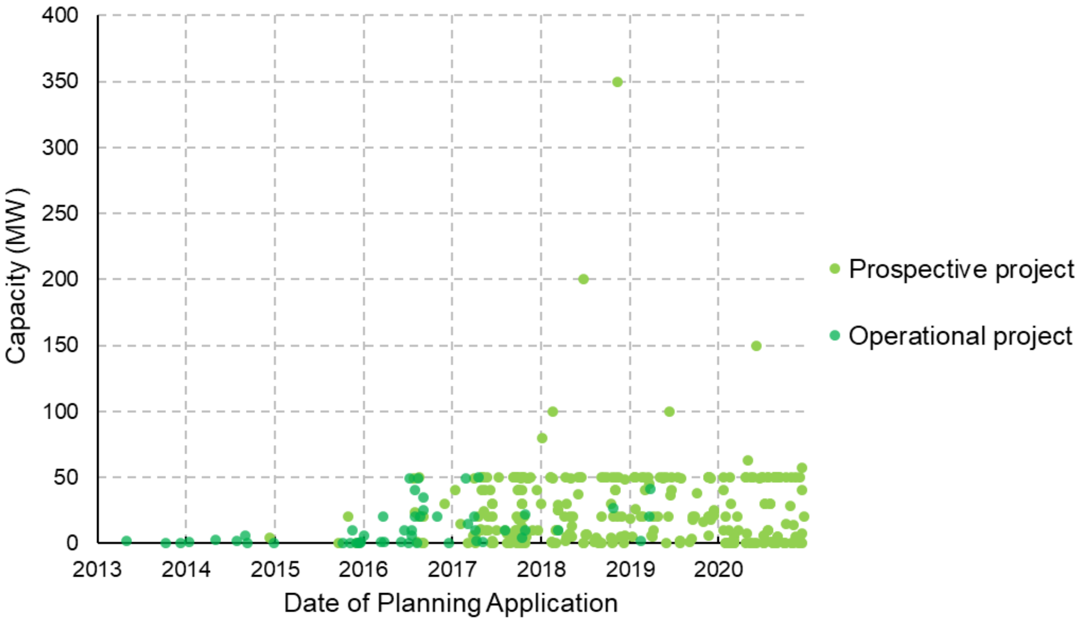
Source: BEIS Renewable Energy Planning Database (December 2020).

Figure 5 shows the capacity of storage projects at different stages of project development; a project only appears once in the chart, based on the most recent change in status. For example, a project that started construction in 2018 and become operational in 2019, would only be shown in the 'operational' category in the 2019. Pumped hydro projects are generally much larger than battery projects. There are fewer pumped hydro projects in the pipeline, and no projects have applied for planning permission since 2018.

The deployment of battery projects peaked in 2018, with around 400MW becoming operational. Deployment fell to around 100MW in 2019, and around 50MW in 2020, with a further 300MW under construction across both years. It is likely that changes to capacity market de-ratings and greater competition for frequency response services (see sections below) reduced the business case for battery assets resulting in a slowdown in projects coming forward in 2019 and 2020.

There is substantial storage capacity in the planning pipeline. At the end of 2020, around 6GW (5.5GW batteries, 300MW pumped hydro) of projects were awaiting construction having had a planning application approved, and a further 3GW (1GW batteries, 2GW pumped hydro) had submitted planning applications. There is uncertainty about the number of projects which will progress to construction and become operational. For example, over 2.5GW of battery projects had planning approved prior to 2019 but have not progressed to construction or operation. It is possible that these projects have not been able to attract investment and may no longer be progressing. Monitoring the development of the pipeline is important to understand the scale of future deployment, as well as identifying the proportion of projects that do not progress.

Figure 6: Capacity of battery projects by time of planning application



Source: BEIS Renewable Energy Planning Database.
Note: We define 'prospective' as projects whose status is either 'Application submitted', 'Permission granted', 'Appeal granted' or 'Under construction' where the end capacity is known.

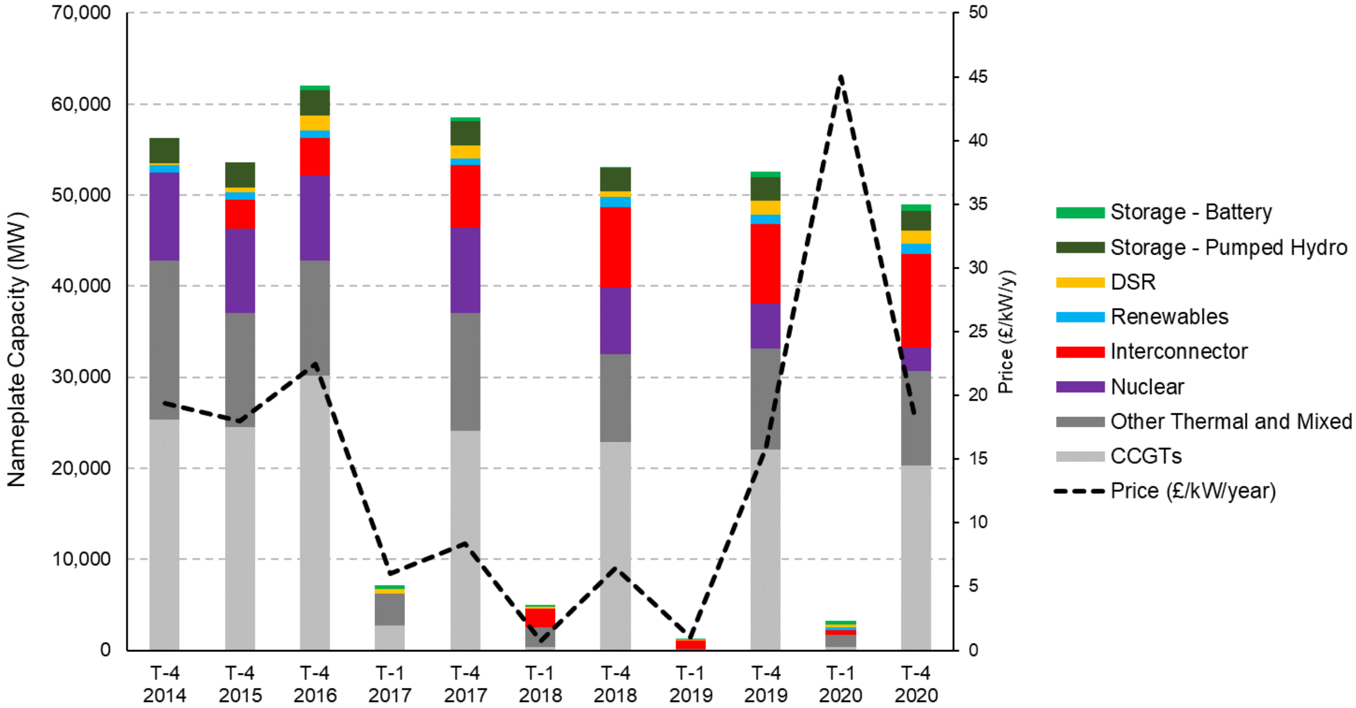
Figure 6 shows the size of battery projects at the date of their planning application. There is a clear clustering of battery projects at or just below the 50MW capacity threshold; one quarter of all projects are sized between 49 and 50MW. This distortion was primarily created by the Nationally Significant Infrastructure Projects (NSIP) capacity threshold of 50MW. In July 2020 secondary legislation was passed which removed storage from the NSIP regime; this came into force in December 2020. Projects can now make sizing decision based on economic factors, rather than being constrained by the NSIP regime. We therefore anticipate an increase in the number of projects above 50MW applying for planning permission.

Reforming markets to reward flexibility

Capacity Market

The Capacity Market ensures security of electricity supply by providing a payment for reliable sources of capacity. The Capacity Market is important for encouraging new investment as longer-term contracts (up to 15 years) are available for new build projects. Auctions are usually held 4 years (T-4) and 1 year (T-1) ahead of delivery. A capacity contract can provide part of the revenue stack for flexible technologies. Payments are determined by a de-rating factor[11] which is calculated based on the technology's contribution to system security.

Figure 7: Capacity Market auctions by technology type



Source: National Grid ESO, Capacity Market Registers.
Note: "Other Thermal and Mixed" includes coal, open cycle gas turbines, gas reciprocating engines, biomass and mixed technologies.

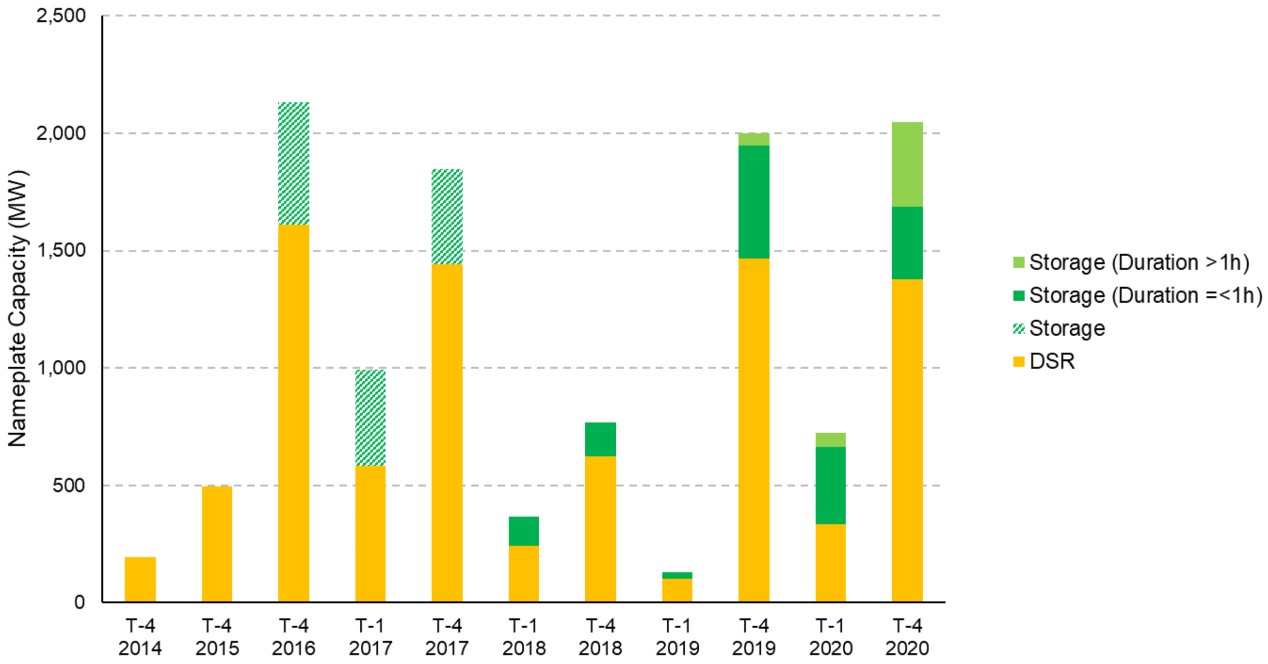
The proportion of flexible technologies winning contracts is relatively low. Combined Cycle Gas Turbines (CCGTs), other thermal technologies and nuclear make up the majority of capacity (see Figure 7). DSR and battery storage make up, on average, just under 5% of T-4 auction capacity, and a higher proportion of T-1 auctions (around 10%).

Lower auction prices and changes to de-rating factors have affected the revenues for flexible technologies. Clearing prices fell from around £20/kW/y in the first three T-4 auctions, to around £5/kW/y. However, the price returned to £15/kW/y in the 2019 T-4 auction, and £18/kW/y in the T-4 2020 auction. In addition, the de-rating for storage was updated in 2017. In

11 De-rating is a measure of the capacity that a unit is likely to be technically available to provide at times of peak demand, which is specific to the unit's technology type and individual characteristics. Units that are less likely to be available at peak demand have a lower de-rating.

the first three T-4 CM auctions, all storage was de-rated at 96%. However, in 2017, the ESO updated its approach to capture the security of supply contribution more accurately for limited duration storage, resulting in lower de-rating factors. For example, the de-rating for 1-hour storage fell to around 20%.

Figure 8: Capacity Market auctions by technology type (DSR and battery storage)



Source: National Grid ESO, Capacity Market Registers.
Note: Prior to 2018 data on the duration of storage projects was not available.

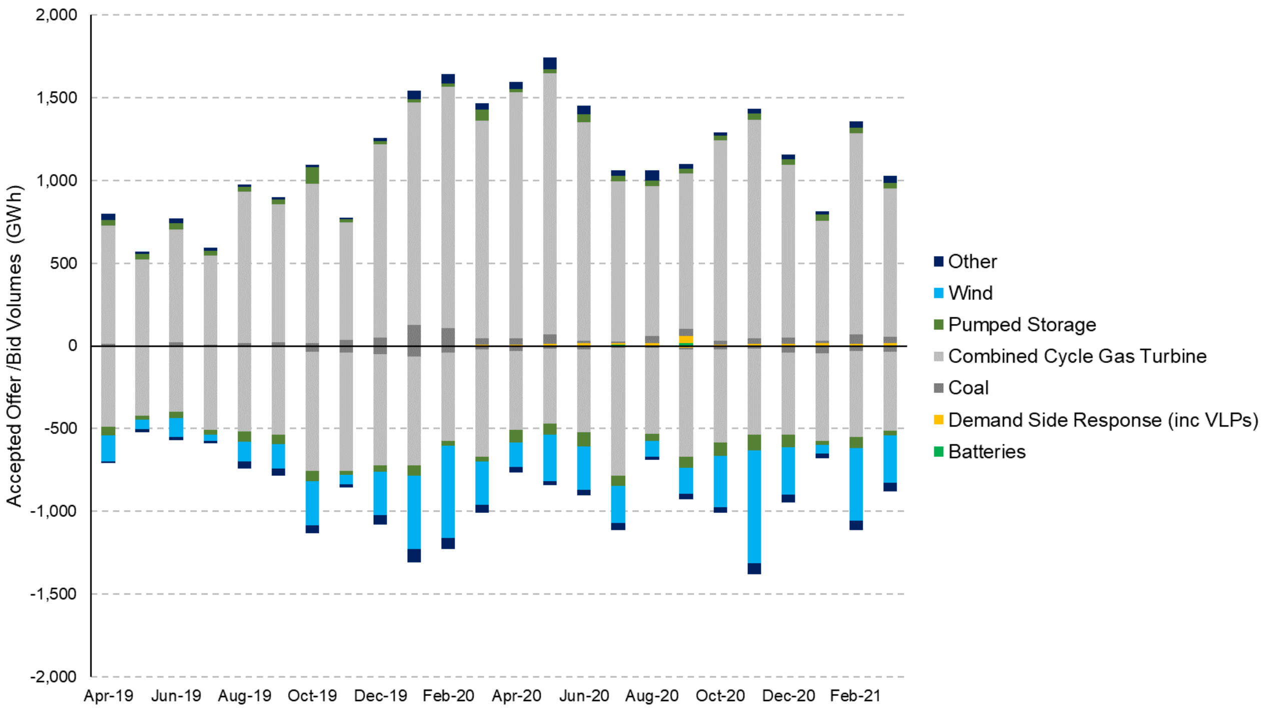
DSR has won capacity contracts in all auctions, while batteries first won contracts in the T-4 2016 auction. Since the T-4 2016 auction, the capacity of DSR and storage has been relatively stable in the T-4 auctions, with around 1.5GW of DSR and 0.5GW of storage winning contacts, although the capacity of both technologies fell in the T-4 2018 auction. Flexible technologies maintained their share of capacity in the in the latest T-4 2020 auction, around 0.7GW of battery projects, and 1.4GW of DSR secured capacity market contracts.

In the latest auction there has been a shift to longer duration storage projects. Around 50% of battery capacity was greater than 1-hour duration in the T-4 2020 auction, compared to only around 10% in the previous T-4 auction. We anticipate that the proportion of longer-duration assets will continue to increase in the future as battery capital costs fall and these assets have greater opportunity for revenues in arbitrage markets (such as the balancing mechanism and wholesale market) and the capacity market (as they have higher de-rating factors).

Balancing mechanism

The Balancing Mechanism is the ESO's primary tool for balancing electricity supply and demand close to real time. When there are imbalances between supply and demand or other system operability challenges, the ESO will accept a 'bid' (decrease in generation or increase in consumption) or 'offer' (increase in generation or reduction in consumption). Prices in the balancing mechanism are volatile (relative to the wholesale market), providing an opportunity for flexible assets to make increased revenues. Several changes over the last couple of years have opened up access to flexible technologies, including a reduction in the threshold of participation from 100 MW to 1 MW and the introduction of the Virtual Lead Party role for aggregators.[12]

Figure 9: Monthly balancing mechanism volumes (all technologies)

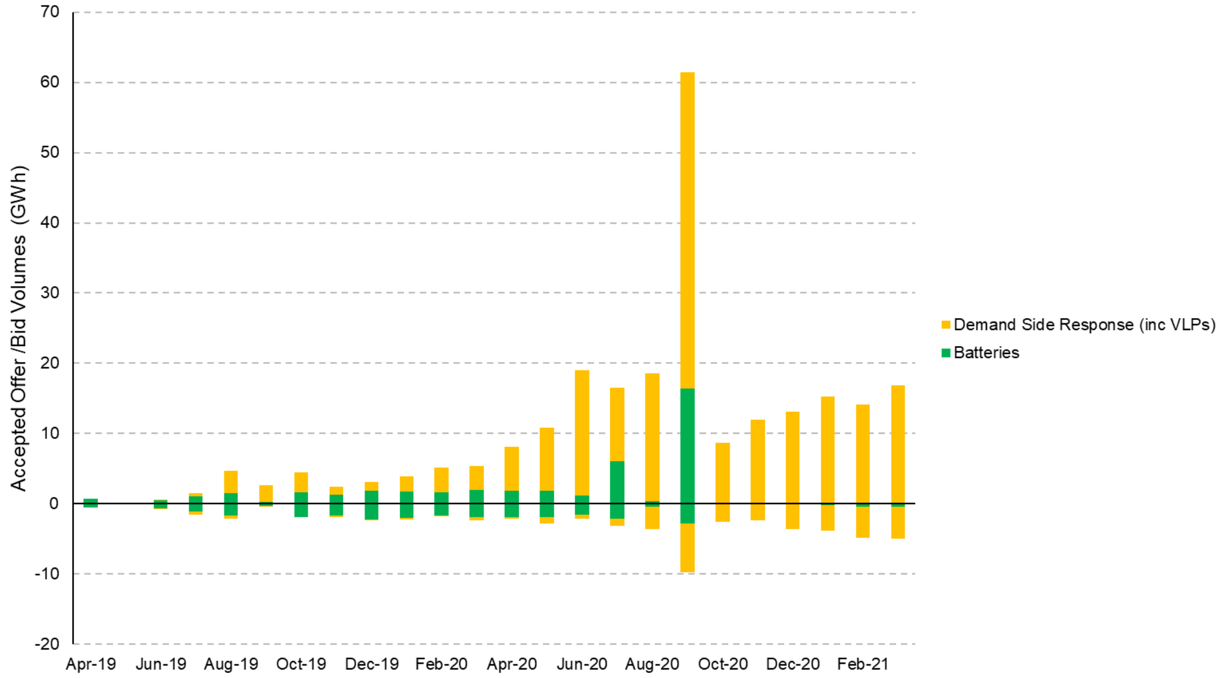


Source: Elexon.
Note: "Other" includes bioenergy, hydro, and other thermal technologies. 'Bids' (decrease in generation or increase in consumption) are shown as negative volumes below the x-axis, 'Offers' (increase in generation or decrease in consumption) are shown as positive volumes above the x-axis.

The balancing mechanism is dominated by large thermal assets, with CCGTs making up around 80% of the total volumes in 2020 (see Figure 9). Wind makes up the second largest proportion of bid volumes; wind bids are usually accepted to deal with system operability challenges, such as network constraints. Battery storage and DSR make up a very small proportion (less than 1%) of total balancing mechanism volumes.

[12] Under the Balancing & Settlement Code framework, independent aggregators are known as VLPs. Independent aggregators are parties who bundle changes in consumer's loads or distributed generation output for sale in organised markets and who do not simultaneously supply the customer with energy.

Figure 10: Monthly balancing mechanism volumes (DSR and battery storage)



Source: Elexon.
Note: 'Bids' (decrease in generation or increase in consumption) are shown as negative volumes, 'Offers' (increase in generation or decrease in consumption) are shown as positive volumes.

Figure 10 shows balancing mechanism volumes for battery and DSR units. The first battery to enter in BM was in early 2019, while DSR providers first entered in mid-2019. Virtual lead parties (VLPs) are also now participating in the balancing mechanism. The first balancing mechanism transaction from a virtual lead party was made by Flextricity in April 2020. As of April 2021, five virtual lead parties had entered the balancing mechanism registering 13 assets.

The volume of accepted bids and offers from DSR and storage has steadily increased over the last 18 months, with the majority of the increase coming from DSR providers. In September 2020, four battery units participated in the "Reserve from Storage in the Balancing Mechanism" trial.[13] This led to a substantial increase in the volume of accepted bid/offer volumes from flexible units. (Note, two of these batteries were registered as VLPs, so are categorised as DSR in Figure 10). Since October 2020, the volume from battery assets has fallen, as projects have changed their business model by entering other markets (see Dynamic Containment section).

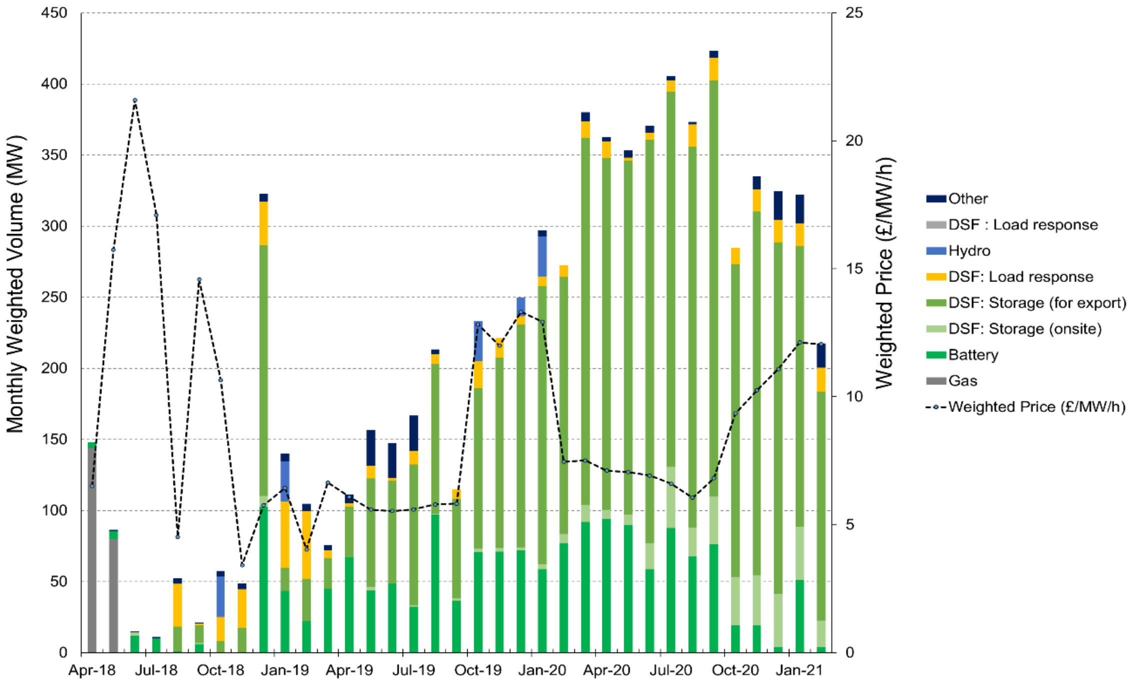
Although the volumes from low carbon flexibility technologies in the balancing mechanism remain small, the increasing overall volumes (due to higher DSR) suggest that more projects are beginning to move to a business model that includes trading in the balancing mechanism.

[13] National Grid ESO (2020), Trial Review: Reserve from storage in the BM, https://data.nationalgrideso.com/plans-reports-analysis/covid-19-preparedness-materials/r/trial_review_-_reserve_from_storage_in_the_bm

Frequency response

The ESO procures a range of frequency response services.[14] These services provide short-term increases or decreases in generation (or demand) in response to changes in system frequency. Units typically must be able to respond in seconds and be able to sustain the service for up to 30 minutes until other units can be synchronised to balance the system. The fast response times make flexible technologies, particularly batteries, well suited to these services.

Figure 11: Monthly firm frequency response (FFR) volumes and price



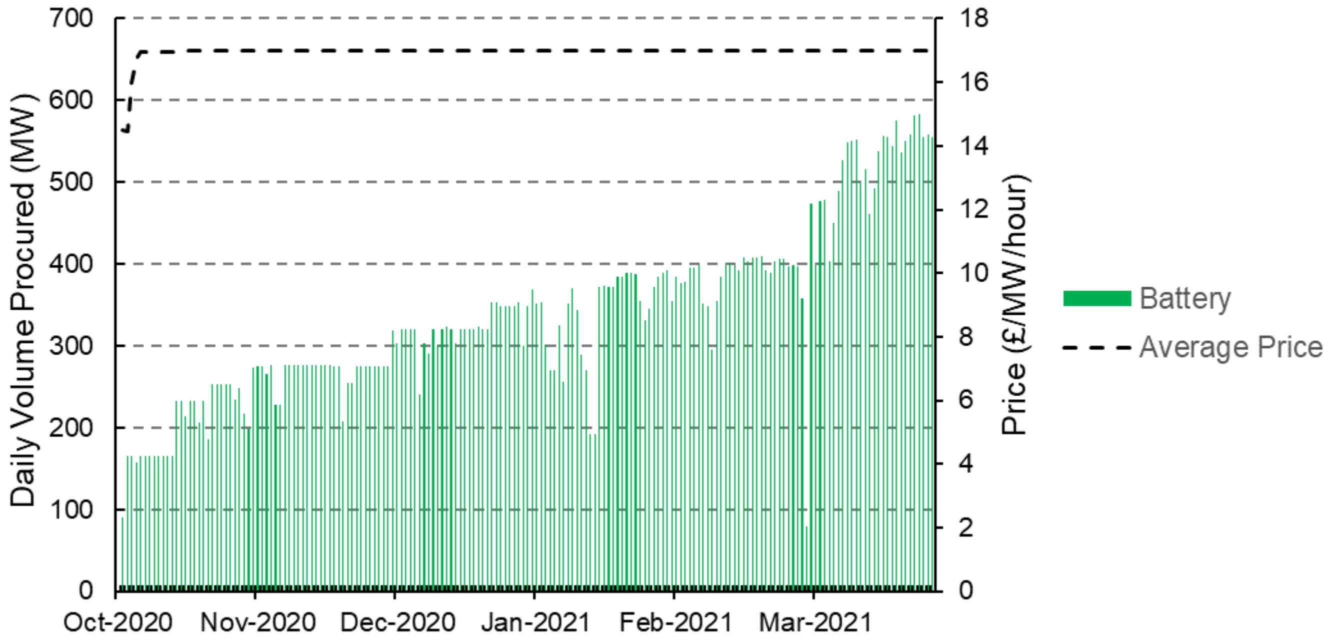
Source: National Grid ESO.
Note: Volumes are based on secondary response volume for the dynamic service. Price is calculated availability fee divided by weighted duration. Technology categorisation is provided by National Grid ESO, DSF stands for demand side flexibility. We assume that Battery, DSF: Storage (for export) and DSF: Storage (onsite) are predominately battery technologies, while DSF: Load response is predominately DSR.

Figure 11 shows that the volume of dynamic firm frequency response has increased significantly since 2018, and that battery storage now supplies the vast majority of this service. Across 2020, the volumes of firm frequency response generally increased; the fall in contracts awarded from October through to the end of 2020 was due to the seasonal trend in frequency response requirements. In the longer-term, the roll-out of the new frequency response services, such as Dynamic Containment, will lead to a reduction in FFR requirements as these services gradually replace the firm frequency response market.

[14] Frequency response is provided through various services. We focus on Monthly Firm Frequency Response (FFR) and Dynamic Containment (DC). There is also i) Mandatory Frequency Response (MFR) - a service obligation for licensed generators ii) Enhanced Frequency Response (EFR) – a one-off tender resulting in 220MW of 4 year contract that began in 2017/18 iii) Weekly Frequency Response Auction Trial - since July 2019 the ESO has been trialling the procurement of FFR on a weekly basis.

The price of firm frequency response has fluctuated over the last 3 years. As battery units entered the market in late 2018, competition drove down the price to around £5/MW/h (prices usually increase in the winter months as some battery units are used to avoid Triad charges[15]). The introduction of Dynamic Containment in October 2020 (see below) is also likely to have contributed to recent higher firm frequency response prices, as some assets switch to the dynamic containment market this dilutes the competition for firm frequency response services.

Figure 12: Daily dynamic containment volumes and prices.



Source: National Grid ESO.

In October 2020, the ESO began procuring the first of a suite of new response products: dynamic containment. The soft launch of the dynamic containment service will last six months (until April 2021). This service is procured at day-ahead and signals a move away from longer term contracts towards more real-time procurement. Dynamic containment requires faster acting assets than firm frequency response, for example, assets must be able to respond in 0.5 seconds. The market is technology-neutral, but to date only battery storage projects have been able to meet the full suite of service requirements.

Error! Reference source not found.2 shows that the daily volume of dynamic containment has steadily increased from around 90MW when the service was launched, to around 500MW in March 2021. However, the procured volume is still below the ESO's service requirement. The requirement was 500MW in the first months of the service, rising to around 1.4GW in summer 2021. The undersupply has meant that prices have remained at, or near, the implicit cap of £17/MW/h. This provides a premium over the monthly FFR service, but the fast response speeds and need for high quality monitoring equipment means that not all flexibility assets can qualify without hardware upgrades.

[15] Triads are the three half-hour settlement periods with highest system demand. The ESO uses them to determine charges for demand customers with half-hour metering and payments to licence-exempt distributed generation.

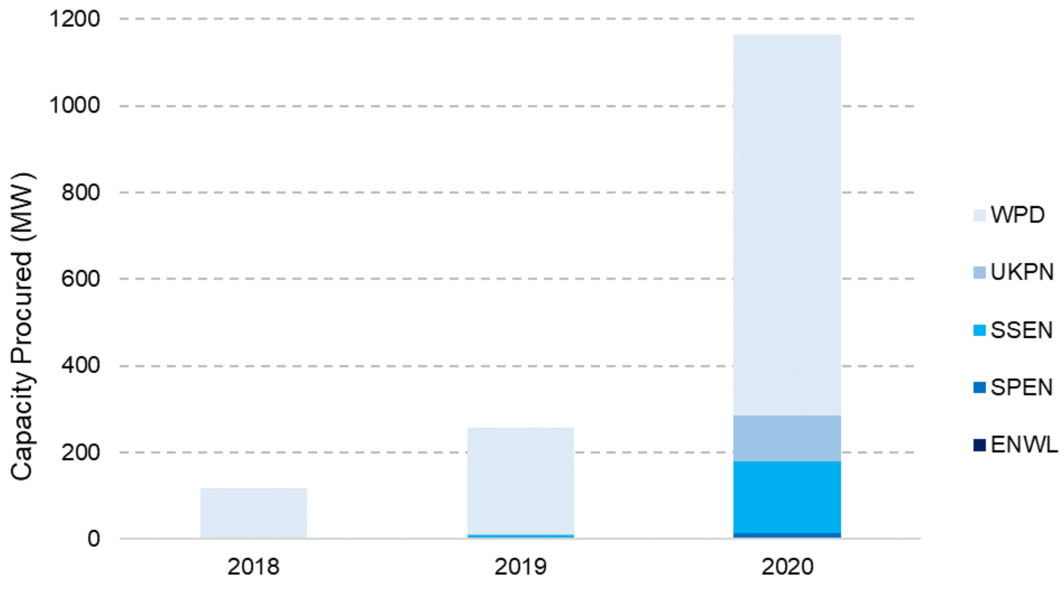
Both firm frequency response and dynamic containment markets have provided substantial revenue opportunities. We expect that the business models for most battery assets have included these services as an important part of their revenue stack. The full launch of dynamic containment and further response services[16] from the ESO is likely to provide additional demand for these assets which could encourage new projects to come forward.

[16] Future response services include Dynamic Moderation and Dynamic Regulation.

Distribution-level flexibility markets

Distribution Network Operators (DNOs) began awarding contracts for flexible capacity in constrained areas of the distribution network for delivery in 2018. A network constraint occurs when the network is unable to transmit power to the location of demand. This can be due to the limited capacity of the network or due to other operation challenges. Historically, DNOs had limited alternatives to undertaking network reinforcement to relieve constraints. With increasing volumes of flexible demand and generation connected to distribution networks, that is no longer the case. Procuring flexibility from users connected in constrained parts of the network can be a cost-effective alternative method for relieving constraints, avoiding expensive network reinforcement, and ultimately reducing costs to consumers.

Figure 13: ***Volume of flexibility tenders by distribution network operator***[17]



Source: Energy Networks Association.
Note: Total capacity procured is calculated by summing the peak capacity contracted for all the DNO services. ENWL procured 3MW of capacity in 2020 which is not visible on the graph.

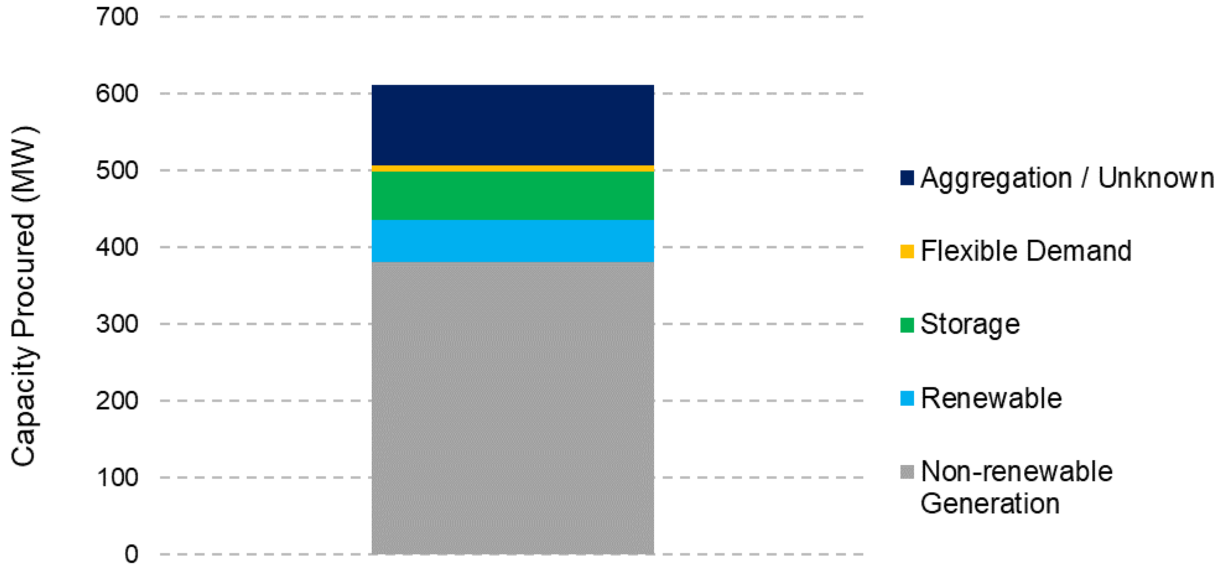
Figure shows the annual volume of DNO contracted flexibility has increased from around 100MW in 2018, to around 1.2GW in 2020. We have seen DNOs adopt and start to procure a standardised set of services across all regions, along with standardised contractual arrangements. In 2018, only WPD procured services, while five of the six DNOs contracted services for 2020. WPD still make up the majority of contracted capacity, although both SSEN and UKPN procured over 100MW in 2020.

DNO flexibility markets provide a new revenue stream for flexible assets, but this is still a maturing market and procured capacities are small compared to other markets. There will be many flexible assets that will not be located in areas where DSO flexibility services are needed. Services are necessarily location-specific and can only be provided by assets in a

[17] WPD: Western Power Distribution, UKPN: UK Power Networks, SSEN: Scottish and Southern Electricity Networks, SPEN: Scottish Power Energy Networks, NPG: Northern Power Grid, ENWL: Electricity North West Limited.

given geographical area (and therefore connected to a specific part of the network). This has resulted in low liquidity and some auctions have seen requirements unfulfilled. However, for assets located in constrained parts of the network, services can be highly valuable with utilisation payments up to £600/MWh[18]. We would expect to see a continuing upward trend in procurement volumes as these markets develop. Some DNOs have already procured services for 2021 and future years.

Figure 14: Volume of distribution network owner flexibility tenders by technology (2020)



Source Energy Network Association.
Note: Technology mix is based on an approximate aggregation across all products.

Figure shows the technology mix for 2020 DNO flexibility tenders. To date the largest providers of these services have been non-renewables generation assets, such as gas reciprocating engines. However, contracts have been won by a range of technologies, including battery storage and flexible demand (commercial and industrial users and electric vehicles). The technology mix is dependent on the assets that are available in constrained parts of the network. Increased demand from heat and transport electrification is likely to lead to a greater number of constrained areas, but this could also provide opportunities for electric vehicles and heat pumps to offer DNOs flexibility services. These services also offer the opportunity for smaller assets to enter markets, the minimum size threshold is just 100kW for many services (compared to 1MW for many ESO services).

[18] Utilisation payment for restore services £600/MWh https://www.flexiblepower.co.uk/flexibility-services

Next steps

This document is the first iteration of our monitoring framework, based on initial stakeholder feedback, including our workshop in May 2020. We recognise that this is the first step to an effective monitoring strategy:

- Our indicators will need to expand and adapt to the changing landscape. New markets for flexibility will emerge and new data will become available. We will review the indicators to ensure they are fit-for-purpose.
- The first set of indicators are broadly aligned to the chapters in the Plan, but future iterations of the monitoring framework will look to link indicators to the more detailed outcomes identified in the Plan list of actions where appropriate.
- Stakeholders are best positioned to identify key indicators for assessing the progress of system flexibility and remaining market barriers. We will work closely with stakeholders to assess the indicators needed to measure the outcomes identified in the plan and to understand further outcomes that are important to consumers and industry that should be reflected in our monitoring framework.

For this first iteration of the monitoring report, we have only selected publicly available data. We recognise that existing public data does not capture all the information that will be needed to track the progress of flexibility going forward. Some data will already be collected but is unpublished, while other areas will require new data to be collected. Rather than summarising unpublished data in our monitoring framework, it would be preferable if these datasets were available to all stakeholders. We will use the monitoring framework as a tool for improving the accessibility of data by working with stakeholders to identify and publish new data where appropriate. Future work should look to develop the evidence base to better monitor the progress of flexible technologies across the system. We have already identified a number of areas where further monitoring data would be valuable:

- Consumer tariffs and behaviour – the number of consumers on time-of-use tariffs and how consumers respond to these tariffs
- Domestic and small-scale smart technologies – deployment of assets and their smart functionality (e.g., batteries, smart electric vehicle chargers and smart heat pumps) at residential and business premises.
- Aggregated services – a better understanding of the technologies that make up aggregated portfolios
- Carbon intensity of flexibility markets – standardised reporting of carbon emissions across ESO, DNO and other markets.

Going forward we will continue to engage with stakeholders across all aspects of our monitoring strategy. We will provide opportunities for stakeholders to give feedback on our first monitoring framework and gather views on areas for future work. We will also seek views on how to share monitoring data with stakeholders on an on-going basis, including which organisation should be responsible for maintaining the monitoring strategy and the format of the report.

Data sources

GB electricity generation mix and deployment of low carbon flexibility
Energy Trends, BEIS, https://www.gov.uk/government/statistics/electricity-section-5-energy-trends (Table 5.1)

Future Energy Scenarios, National Grid ESO, https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2020-documents

Facilitating flexibility from consumers
Smart Meter Statistics, BEIS, https://www.gov.uk/government/collections/smart-meters-statistics

Vehicle Licensing Statistics, Department for Transport, https://www.gov.uk/government/statistical-data-sets/all-vehicles-veh01 (VEH0171)

Renewable Heat Incentive Statistics, BEIS, https://www.gov.uk/government/collections/renewable-heat-incentive-statistics

Removing barriers to flexibility on the grid
Renewable Energy Planning Database, BEIS, https://www.gov.uk/government/collections/renewable-energy-planning-data

Capacity market
Capacity Market Registers, National Grid ESO, https://www.emrdeliverybody.com/CM/Registers.aspx

Balancing mechanism
Elexon via EnAppSys, https://www.netareports.com/

Registered Balancing mechanism units, Elexon, https://www.elexonportal.co.uk/REGISTEREDBMUNITS

Frequency response
Firm Frequency Response (FFR) Post Tender Reports, National Grid ESO, https://data.nationalgrideso.com/ancillary-services/firm-frequency-response-post-tender-reports

Dynamic Containment Data, National Grid ESO, https://data.nationalgrideso.com/ancillary-services/dynamic-containment-data

Distribution-level flexibility
DNO Flexibility Tenders, Energy Networks Association, https://www.energynetworks.org/assets/images/ENA%20Consolodated%20Flex%20Figures%202020-PUBLISHED.xlsx

This publication is available from: www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021

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