SMART POWER

NATIONAL
INFRASTRUCTURE
COMMISSION

CHAIR'S FOREWORD

From the morning commute and how we work, to heating our homes and keeping in touch with our friends and family, the quality of our infrastructure is absolutely fundamental to our quality of life.

We all share an interest in better decision making, clearer planning, and more efficient and timely delivery of modern infrastructure.

The National Infrastructure Commission seeks to provide clear thinking, dispassionate analysis and impartial advice to help drive forward vital infrastructure improvements.

The National Infrastructure Commission has begun with studies into the UK's electricity sector, connecting the great cities of the North and London's transport system. *Smart Power* is the first of these reports.

Electricity generation is undergoing fundamental change. Many existing fossil fuel power stations will be decommissioned in the coming 15 years and new sources of generation are coming on stream.

This report does not attempt to address all of the challenges facing our energy sector, but focuses on the benefits we can achieve through building a more flexible electricity system and the steps that will get us there.

Three innovations will help us deliver this – interconnection, storage, and demand flexibility – which have the potential to displace part of the need for new generating capacity, to save money for businesses and domestic consumers and help the UK meet its climate reduction targets. The saving could be as large as £8 billion a year by 2030.

Together, these three infrastructure innovations have the potential to create a leaner, more efficient electricity system at the cutting edge of global technology. This report makes practical recommendations to this end.

Andrew Adonis,
Interim Chair of the National Infrastructure Commission

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SMART POWER: IN BRIEF

Our energy sector is changing fundamentally. Two-thirds of our existing power stations are expected to close by 2030 as our coal, nuclear, and oldest gas fired power stations reach the end of their lives. This report makes recommendations to help ensure that our electricity system is fit for the future.

The Commission's central finding is that Smart Power – principally built around three innovations, Interconnection, Storage, and Demand Flexibility – could save consumers up to £8 billion a year by 2030, help the UK meet its 2050 carbon targets, and secure the UK's energy supply for generations.

PART 1: ALL CHANGE

Our existing infrastructure was designed for a post-war world where homes and businesses were supplied almost exclusively from large fossil fuel generators.

As we modernise and decarbonise our energy system we need to find new ways to manage the network in the most efficient way possible.

This represents a serious challenge and an enormous opportunity. If we get this right, it will provide the efficient, flexible and secure energy infrastructure our country will need to thrive. DECC and Ofgem have already made a start.

PART 2: SMART POWER

In the coming decades the UK is uniquely placed to benefit from three innovations which could help fire a smart power revolution.

Interconnection – connecting our electricity network to our continental neighbours is already bringing down bills and helping to balance the system. More connections to cheap, green power supplies, such as Norway and Iceland could bring great benefits to the UK. Government should redouble its efforts to open new connections.

Storage – technology is accelerating at a remarkable speed. The UK could become a world leader in making use of these technologies, not through subsidies, but by ensuring that better regulation creates a level playing field between generation and storage.

Demand flexibility – A new generation of hi-tech systems means consumers can save money and cut emissions without inconvenience. Government should ensure the UK benefits by improving regulation, informing the public of its benefits and piloting schemes on its own estate.

PART 3: MAXIMISING THE BENEFITS OF A MORE FLEXIBLE MARKET

For the smart power revolution to realise its full potential we must ensure that our networks and systems keep up.

This requires more active management of our local electricity networks, a national system operator able to keep up with an increasingly complex system, and a strategic approach to upgrading our network.

The UK is uniquely placed to lead the world in a smart power revolution. Failing to take advantage would be an expensive mistake.

SMART POWER AT A GLANCE

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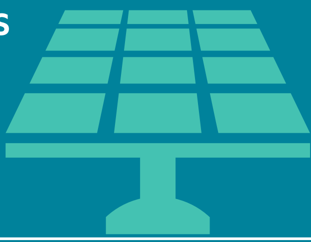
Around two-thirds of our existing power stations are expected to close down by 2030 as our coal, nuclear, and oldest gas fired power stations reach the end of their lives.

Our system must be modernised and decarbonised. To meet the UK's legally binding climate change goal – to cut CO_2 emissions by 80% by 2050 – power stations must be largely decarbonised.

The system must be balanced on a second by second basis, but nuclear and renewable energy cannot be ramped up and down as we currently do with fossil fuel plants.

Climate Change Target = Cut $C0_2$ emmissions

by 80% by 2050



Interconnection
connecting our network to our European neighbours.

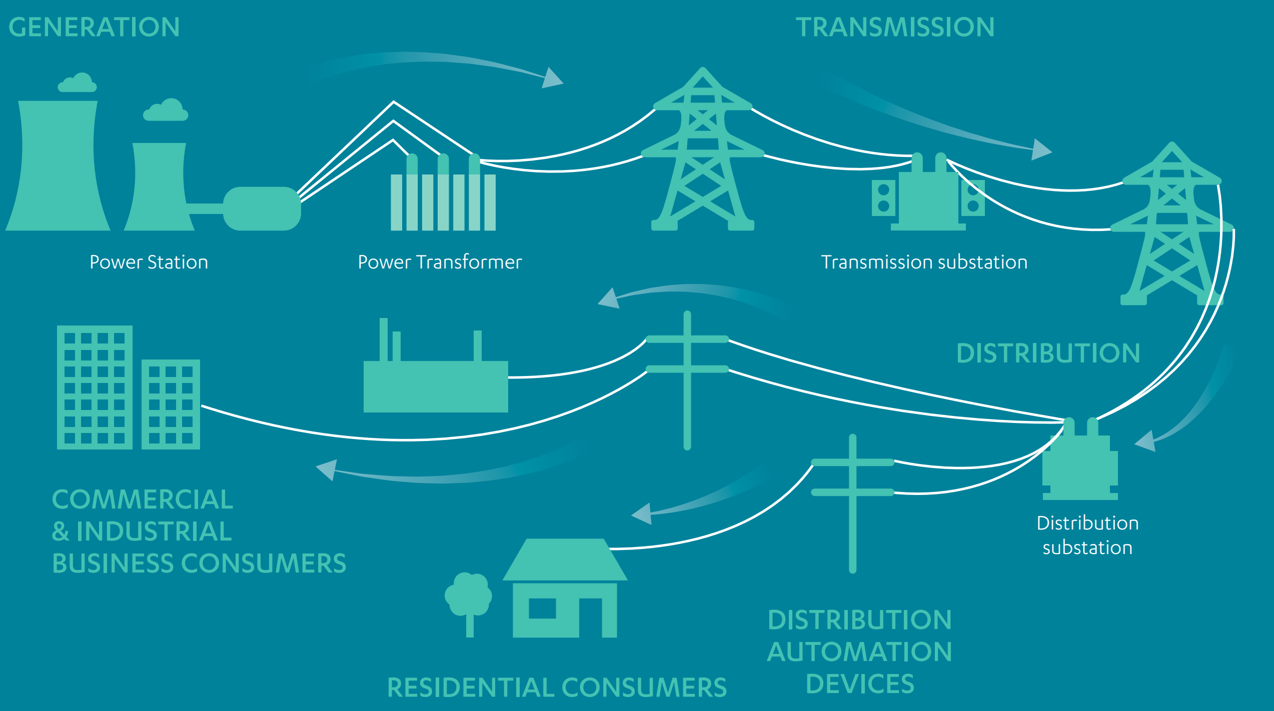
Storage
Allowing users to take energy from the grid to be used when it is needed

Flexible Demand
Allowing consumers to choose how and when they use power to cut costs and emissions without inconvenience.

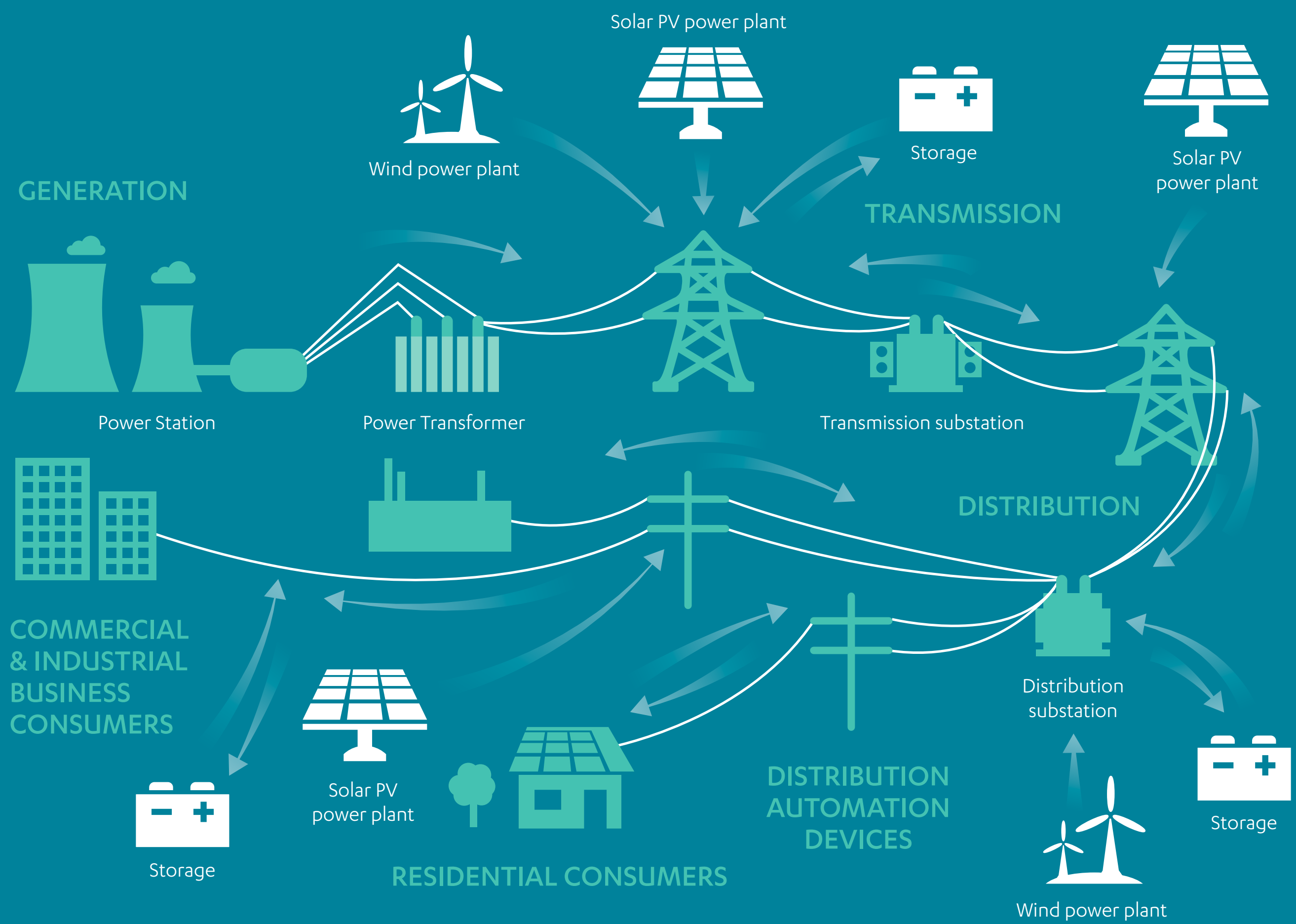
The UK is uniquely placed to lead the world in a Smart Power Revolution. If we get this right we could save consumers up to

£8bn a year

TRADITIONAL POWER SYSTEM



FUTURE POWER SYSTEM



EXECUTIVE SUMMARY – SMART POWER

The National Infrastructure Commission (NIC) was asked to consider how infrastructure and policies to promote interconnection, storage and demand flexibility could create a more efficient and cheaper electricity system. The Commission has engaged with a range of stakeholders across industry, government and civil society, and received more than 130 formal submissions to its Call for Evidence.

The Commission's central finding is that Smart Power – principally built around three innovations, Interconnection, Storage, and Demand Flexibility – could save consumers up to £8 billion a year by 2030, help the UK meet its 2050 carbon targets, and secure the UK's energy supply for generations.

PART ONE: ALL CHANGE

Around two-thirds of our existing power stations are expected to close down by 2030 as our coal, nuclear, and oldest gas fired power stations reach the end of their lives.

To meet the UK's legally binding climate change goal – to cut $C0_2$ emissions by 80% by 2050 – power stations must be largely decarbonised. Complete future reliance on unabated industrial fossil fuel power stations is unsustainable.

There is a near term need to build new sources of power to ensure we have the electricity we need. Over the next decade, new and more diverse sources of electricity generation will need to come on stream, including more renewable energy, new gas fired plants and new nuclear capacity.

Nuclear power is inflexible: nuclear plants are best run at a continuous rate - delivering a stable base load of power rather than ramping up and down to match demand. The shift to more low carbon technologies will also mean more smaller power stations connected to the distribution network, for example onshore wind, solar power, and combined heat and power plants.

Alongside a generational shift in our supply, demand for electricity is also likely to change as new parts of our economy start to electrify such as heat and transport.

But the underlying mechanics of the electricity system won't change. Electricity demand and supply must be balanced on a second by second basis in order to maintain secure supply. If electricity supply is insufficient to meet demand or exceeds it the system can become unstable, ultimately leading to blackouts. The network needs to be resilient to unexpected events, such as a surge in demand or a power station going offline without inconveniencing consumers. In order for the network to continue operating efficiently, future requirements will demand a smarter way of controlling generating capacity and demand in the UK.

This will come partly from increased interconnection to overseas energy suppliers, significantly increased storage and more efficient flexibility of demand. The NIC has examined the potential of these innovations, and we believe them to be hugely significant to future policy and infrastructure.

PART TWO: SMART POWER

In the coming decades three innovations will help fire a smart power revolution. The UK is uniquely placed to benefit from each of them.

Interconnection

Interconnection is the physical linking of electricity markets across borders which allows the trading of electricity. It allows the UK to connect our network to those of our neighbours.

Great Britain has historically had low levels of interconnection relative to other countries, due to the distance to other countries and the need to lay subsea cables.

Interconnectors offer a number of benefits to the UK and are a key source of flexibility to the electricity system. They are one of the few existing technologies that can shift large volumes of electricity from where it isn't needed to where it is. By doing this they have the potential to lower prices for consumers, improve the investment case for power stations, help us meet our carbon targets at a lower cost and improve security of supply.

Interconnectors can be thought of as both additional generation capacity and power exporters. This is because they allow electricity to be imported at times of peak demand but are also able to sell electricity abroad when we have more than we need.

A better connected network

Great Britain currently has 4 GW of interconnection capacity, around 5% of total generation capacity, through four interconnectors - two to the island of Ireland, one to France and one to the Netherlands. The existing 'cap and floor' regulatory regime has started to bring forward a healthy pipeline of interconnection projects that will deliver significant benefits to UK consumers. By the early 2020s we expect to have around 11.3 GW of capacity with new connections to France, Norway, Denmark, Ireland and Belgium, and other projects are in train.

Great Britain currently has 4GW of interconnection capacity, around 5% of total generation.

The role of interconnectors will evolve over time and will be determined by factors such as the precise makeup of the UK's generation mix and the markets we interconnect with.

Progress so far has been good but there is potential for more.

Recommendation 1: Government should pursue additional interconnectors with other European countries where the benefits are most significant.

Interconnection investment decisions should continue to sit primarily with the private sector but there is a role for government-led diplomacy to unlock those markets that can offer potentially large benefits to UK consumers. The government should therefore focus its efforts on exploring increased interconnection to markets with abundant sources of flexible low carbon electricity, such as Norway and Iceland.

Storage

Storage allows consumers and suppliers to take energy and store it so that it can be used when it is most needed.

Electricity prices vary throughout the day, and across the year. When demand is higher, prices rise. Storage technology allows consumers to buy electricity when it is cheap and use it later when it is needed.

There are a number of ways electricity can be stored. Today, our main source of storage is through pumped hydro – simply converting electric energy into potential energy and back by moving water up and down a hill. There is, however, an increasing range of alternative ways to store energy including; chemical batteries, compressed air and supercapacitors.

Huge technological advances, tremendous potential, no subsidies required

Electricity has historically been difficult and expensive to store.

However, over the last decade there has been a great deal of innovation in electricity storage technologies driven mostly by consumer electronics like mobile phones and investment in electric vehicles.

This rapidly evolving environment has driven innovation and reduced costs. For example, the cost of lithium ion batteries has decreased from more than $3,000/kWh in 1990 to less than $200/kWh today.

These technologies are now on the verge of being able to compete with power stations for some of the services they provide.

Crucially, storage technology will not need subsidies to be attractive to investors – businesses are already queuing up to invest.

Regulation, on the other hand, does require attention. When our electricity markets were designed these technologies did not exist. The result is a market that is opaque, and operated in a way that unintentionally disadvantages storage providers; preventing them from participating across the various electricity markets.

For example, storage assets face 'double charging' for the various government levies that are added to electricity costs. These taxes are placed on the electricity used to charge up the store and again when the electricity is exported.

Even if storage could undercut generators, providers currently struggle to get finance because the lack of transparency in the market makes it difficult to put together a compelling business case.

The result is that barriers to the market are hindering a technology that could bring down bills, prevent the need for additional power stations and help secure the power mix that could ensure we hit our legally binding climate change targets.

Not only can storage can help reduce the impact of peak demand and provide demand for power stations at other times of day, it also has the potential to ease constraints on our grids.

Like a river with an off flow to a reservoir, storage can allow the network to siphon off electricity rather than being forced to curtail generation – for example putting an end to paying wind farms not to produce electricity, which currently costs £90 million a year.

The cost of lithium ion batteries has decreased from more than

$3,000/kWh in 1990

to less than

$200/kWh today

Network owners are only just starting to make use of these technologies, but there is now enormous potential to make storage technologies an integral part of our networks, rather than building more power stations just to meet peak demand, or laying expensive cables.

Recommendation 2: The UK should become a world leader in electricity storage systems. Two steps are required:

a) **DECC and Ofgem should review the regulatory and legal status of storage and remove outdated barriers to enable storage to compete fairly with generation across the various interlinked electricity markets. The reforms should be proposed by Spring 2017 and implemented as soon as possible thereafter.**

b) **Network owners should be incentivised by Ofgem to use storage (and other sources of flexibility) to improve the capacity and resilience of their networks as part of a more actively managed system.**

Demand Flexibility

Demand flexibility covers a broad range of activities that can be undertaken to reduce or shift demand for electricity during peak periods, including adjusting the consumption of electrical appliances or other facilities or deploying off-grid sources of power.

Demand flexibility can allow families and businesses to change how they use electricity. Deploying automated systems to reduce consumption at times of high demand and increase it at times of low demand, will allow consumers can save money and cut emissions without inconvenience.

In addition, demand flexibility can support the integration of low carbon generation such as wind, solar or nuclear. Flexibility in how we consume energy lowers the need for flexibility in supply.

Heading towards a more flexible future

Demand flexibility is commonplace in other countries such as Australia and the US, where it enables them to meet up to 15% of the peak demand for electricity. But demand flexibility is currently underused in the UK, fuelled by an apparent and widespread failure to properly communicate the benefits it provides.

Providers of demand flexibility have stated that they are unable to access the UK's electricity markets on equal terms with generators, including the capacity market. The long term goal for the capacity market must be to ensure a level playing field for the diverse technologies that can participate. In the short term, there are a number of small changes that should be made as soon as possible which will make it easier for demand side solutions to participate.

Demand flexibility is commonplace in other countries, such as Australia and the US, where it enables them to meet up to 15% of the peak demand for electricity.

Some of the best British businesses are already making use of demand flexibility, but there is potential for much wider take up. With the roll out of smart meters in every home in the 2020s, the domestic market for demand flexibility could be significant. Without tackling regulatory and cultural barriers, however, it is unlikely that the potential benefits will be achieved.

There is an opportunity here for UK firms. We are a world leader in the data analytics and software development that can be used to manage energy demand seamlessly: showing what can be achieved will enable these capabilities to be marketed to the world.

Recommendation 3: The UK should make full use of demand flexibility by improving regulation, informing the public of its benefits it can provide and piloting business models.

a) Ofgem should start an immediate review of the regulations and commercial arrangements surrounding demand flexibility with a focus on making participation easier and clarifying the role of aggregators; this should be complete by Spring 2017.

b) DECC should make future changes to the capacity market to reduce the costs and barriers to entry for demand flexibility.

c) DECC, Ofgem and National Grid should ensure that large users and opinion formers are aware of the money saving opportunities that demand flexibility can offer and encourage more industrial and commercial consumers to take part.

d) Pilots focusing on business models which make demand flexibility easy and attractive to consumers should be established and fully evaluated. Government should demonstrate best practice by investigating the scope for demand flexibility on its estate.

PART THREE: MAXIMISING THE BENEFITS OF A MORE FLEXIBLE MARKET

The UK requires a national system operator able to keep up with an increasingly complex system, more active management of our local networks and a strategic approach to upgrading our network.

> National Grid, a privately owned company, is the System Operator for the electricity system in Great Britain. It is responsible for balancing the supply of electricity with demand at the national level, for example by ensuring power stations are on standby in case of a sudden increase in demand and ensuring that the network operates safely, securely and efficiently.
>
> Distribution network owners - a number of privately owned companies - own the lower voltage, local electricity network which is used to deliver electricity to consumers. Some smaller power stations (e.g. a small wind farm or domestic solar panels) are connected to the distribution network, whereas larger power stations connect to the national transmission network. Distribution network owners are responsible for connecting new sources of demand to their networks and carrying out reinforcement investments but do not have a responsibility for managing supply and demand on their networks.

A smarter system operator

Whilst we recognise that there is the potential for a conflict of interest between the roles National Grid carry out, and a case for greater independence, the Commission has found no evidence that the System Operator has acted in a way which has negatively affected consumers. Fundamental change in the immediate term risks delaying action over the more important task of making our networks better run and more efficient. However, it is important for the system operator to be more independent, and National Grid should work to achieve this.

As the system evolves, with more and smaller power stations that are less flexible, increased deployment of storage, greater interconnection, and increased usage of demand flexibility, the role of the System Operator will become significantly more complex. National Grid should therefore be encouraged to invest in the necessary digital infrastructure and capability to optimise the system.

Recommendation 4: The System Operator must create new markets that will allow open competition for the services it procures and ensure it keeps pace with the network it oversees.

a) **The creation of an entirely independent System Operator should not be treated as an immediate priority but should be kept under review in light of progress towards strengthening National Grid's independence.**

b) **Ofgem should consider how it encourages the System Operator to develop new markets to provide ancillary services which allow new technologies to participate more easily. The long term goal must be for a more strategic and transparent approach to the procurement of ancillary services and more cost-reflective charging.**

More active management of our local networks

Most of the potential for storage and demand flexibility will be embedded in local networks.

Those networks have traditionally been used to transport power from the transmission network to consumers and they do this job efficiently.

However, in future, instead of simply transporting power from the transmission network to consumers it is almost inevitable that distribution network owners will be managing small directly connected generators, such as solar and wind, as well as batteries and sources of demand flexibility, with power increasingly flowing in both directions through their systems. This is already starting to happen.

To meet these new challenges as efficiently as possible local networks will require more active management, alongside closer coordination with the national network. Doing this will help support local sources of generation and demand to balance the national system.

Recommendation 5: Enabling the transition to more actively managed local networks should be a government priority. By Spring 2017 DECC and Ofgem should consult and set out how and under what timeframe this transition should best take place.

A strategic approach to upgrading our networks

Ofgem have recently started to incentivise greater innovation and new ways of delivering resilient electricity networks. The implementation of the new RIIO price control framework (Revenue=Incentives+ Innovation+ Outputs (RIIO)) is an excellent first step.

But as the potential for new technologies increases more must be done.

For example, using storage and demand flexibility can save consumers money by postponing or mitigating expensive upgrades and grid reinforcements. Future planning frameworks must enable and incentivise the adoption of these solutions.

A strategic approach to upgrading our networks could deliver large savings to future consumers at low risk to existing consumers at the local level.

Recommendation 6: Where upgrades to our networks are needed Ofgem should continue its work in encouraging network companies to make long term strategic decisions. Whilst this does increase the risk of stranded assets, the Commission believes that if there is a potential net gain to future consumers then this approach may be justified. If network owners are not best placed to manage this risk, they should work with third parties to help facilitate these investments.

PART 1: ALL CHANGE

1 ALL CHANGE

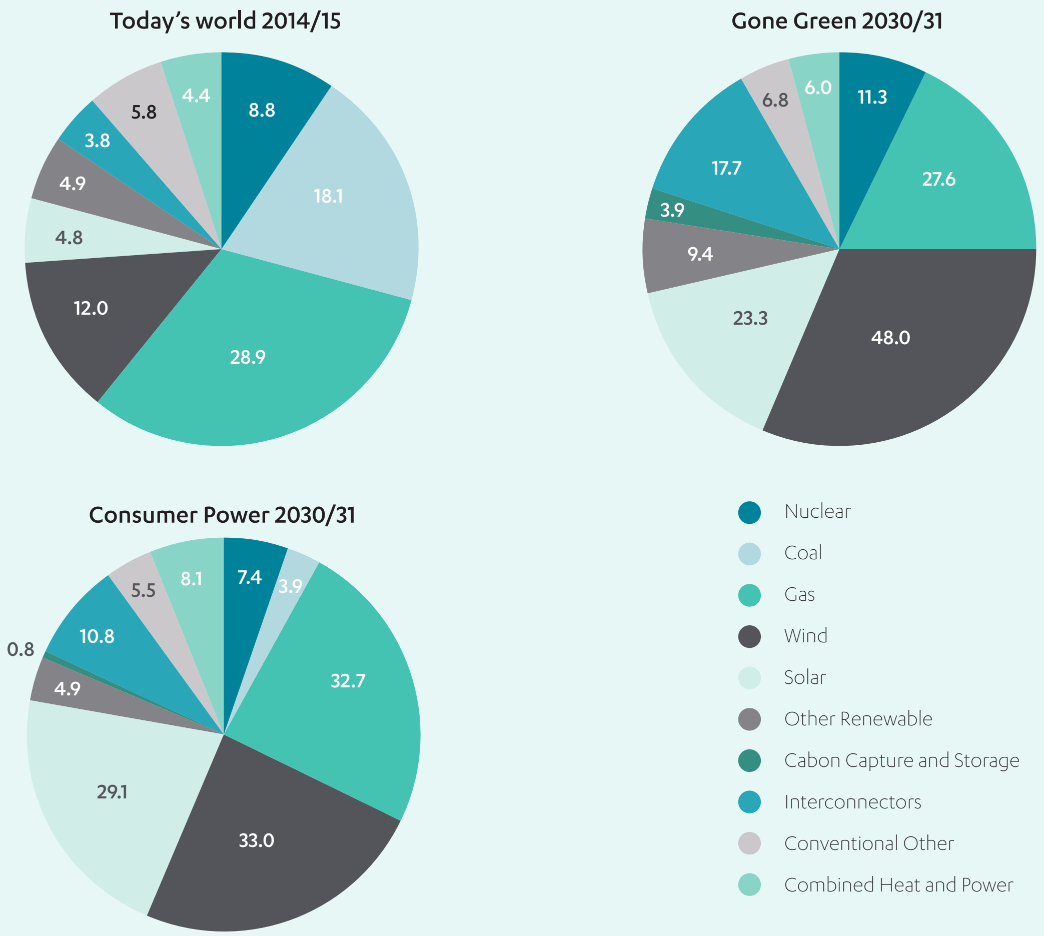
The way we use the electricity network is changing fundamentally

1.1 The UK's electricity system will be transformed over the coming decades. This is being driven by the need to decarbonise our power supplies, our ageing power stations reaching the end of their lives and new technologies changing the way households and businesses use and generate electricity.

1.2 Increasingly our electricity networks, both the large-scale transmission network that moves electricity from one region of the country to another and the more local distribution networks that connect to our homes and businesses, are moving away from linear 'one-way' flows of electricity from power stations to passive consumers.

1.3 Instead we are moving to a system in which generation is distributed more widely across the country and is more variable in its nature and scale. Where technologies such as solar panels are blurring the distinctions between suppliers and consumers of electricity, are able to manage their demand for power more actively. Where new technologies are emerging at an ever-increasing pace.

Generation mix today and possible future scenarios (installed capacity (GW))[1]



1.4 The precise make-up of the electricity system will be driven by how quickly the costs of technologies such as solar panels and storage fall, and to what degree other parts of the economy such as heating and transport turn to electricity. Taking all these factors into consideration, it is hard to predict either the demand for electricity in the future or how it will most efficiently be supplied.

Key participants in the GB electricity market

Generators: Generators own power stations, or other sources of power such as renewables, which they use to generate electricity. Generators either sell their electricity into the wholesale market or have contracts with electricity suppliers

Suppliers: Suppliers buy electricity from either the wholesale market or directly from generators and then sell this to firms and households in the retail market.

Transmission Network Owners: Transmission network owners own the high voltage electricity transmission network. This is used to move electricity long distances across the country. Large power stations are connected to the transmission network. Electricity substations connect the transmission network to the distribution network.

Distribution Network Owners: Distribution network owners own the lower voltage electricity distribution network. This is used to deliver electricity to consumers. Some smaller power stations (e.g. a small wind farm or domestic solar panels) are connected to the distribution network and not the transmission network.

Aggregators: Aggregators offers services to aggregate energy demand or production from different sources to act as one entity in providing services to the grid. This allows them to achieve economies of scale in purchasing power or in managing demand.

The System Operator: National Grid is the System Operator for the electricity system in Great Britain. It is responsible for balancing the supply of electricity with demand at the transmission level and ensuring that the network operates safely, securely and efficiently.

1.5 With around two-thirds of existing power stations set to close by 2030, there is a near term need to build new sources of power to ensure we have the electricity we need.[2]

1.6 To begin with, while renewables will continue to grow as a proportion of the generating mix, it is likely that gas will also need to play an increasing role in our energy system. This is because new gas fired power stations are deliverable to the timescales needed to ensure continuity of supply over the coming decade, produce lower emissions than coal, and provide a relatively flexible source of power which can respond to changes in demand for electricity over the course of the day.

The age of the dominance of industrial fossil fuel power stations is coming to an end

1.7 In the longer term, however, much more significant decarbonisation of the power sector will be necessary. Whilst the precise rate of this decarbonisation and whether it will be driven by carbon prices, government subsidies or regulation is unknown, modelling by the Committee on Climate Change shows that the power sector must be near zero carbon in 2050 if we are to meet our legislated emission reduction targets.[3] This means that we need ultimately to generate more of our power from low or zero carbon sources of electricity, and whilst fossil fuels may still play a role, their emissions will have to be dealt with through carbon capture and storage.

But the underlying needs of an electricity system remain constant

1.8 Despite the changes taking place in and around the system, electricity demand and supply must continue to be balanced on a second by second basis in order to maintain the secure electricity supplies our economy relies on. If electricity supply is insufficient to meet demand, or exceeds what is needed, the system can become unstable, ultimately leading to blackouts.

1.9 Variations in demand are fairly predictable. Therefore, electricity suppliers can work out in advance what they need to purchase from the generators, using a mix of long term contracts and short term trades, to balance out the majority of the changes in demand in different seasons of the year or at different times of the day. This is the wholesale market.

1.10 Whilst the wholesale market is very effective at matching anticipated demand with supply, it is unable to deal with the smaller and less predictable differences that occur in real time. There can be any number of reasons for an imbalance in demand and supply: for example a supplier may have misjudged the demands that its customers will make on the system at a given time or a power station may break down or otherwise be unable to generate the amount of electricity it had anticipated. In these cases the System Operator has the responsibility of bringing the system back into balance, the so called 'balancer of last resort'. It does this by paying for power stations to ramp up or down their supply or customers to change their level of demand in real time through the balancing market.

The transition to low carbon generation presents challenges for balancing supply and demand

1.11 Most lower carbon power sources have quite different characteristics to fossil fuel plant, which limit their ability to manage the changing pattern of demand for electricity at different times of the year and different times of day.

1.12 Coal and gas fired power stations are not dependent on external factors such as the weather to enable them to generate power and can be switched on and off comparatively quickly in response to changing patterns of demand. For these reasons, the System Operator has historically used them as its main tool for balancing the system in real time, in combination with a small amount of extremely fast-starting hydro power to manage the most sudden spikes in demand.

1.13 In contrast, renewable generation is intermittent, with wind farms only able to generate when it is windy and solar power proportional to the amount of sunlight. Nuclear power is best run delivering stable base load power, rather than ramping up and down to meet demand, as the process of turning a nuclear plant on or off is time-consuming and expensive.

1.14 Low carbon power stations are also relatively expensive to build but once constructed are cheap to operate, with the opposite being true for most fossil fuel plants.[4] It would clearly be inefficient and unsustainable to deal with the increased balancing challenge by constructing a large amount of low carbon generating capacity that would only be needed for a few hours of the day to meet peak demand, and more again to manage intermittency.

New generation is often smaller and dispersed

1.15 Renewable installations tend to be smaller and are therefore often connected to the lower voltage distribution network. This has benefits in bringing generating capacity close to the consumer and reducing the demands on the transmission system (and the associated costs) but it also creates a more complicated geographical spread of energy supply and leads to new challenges in managing both local and national networks.

1.16 In particular, with increasing amounts of solar power in the system, managing periods of low demand in the summer will be just as important as managing the high demand we see in the winter, as we may experience a surplus of electricity of in the middle of a sunny day.

We must maintain security of supply

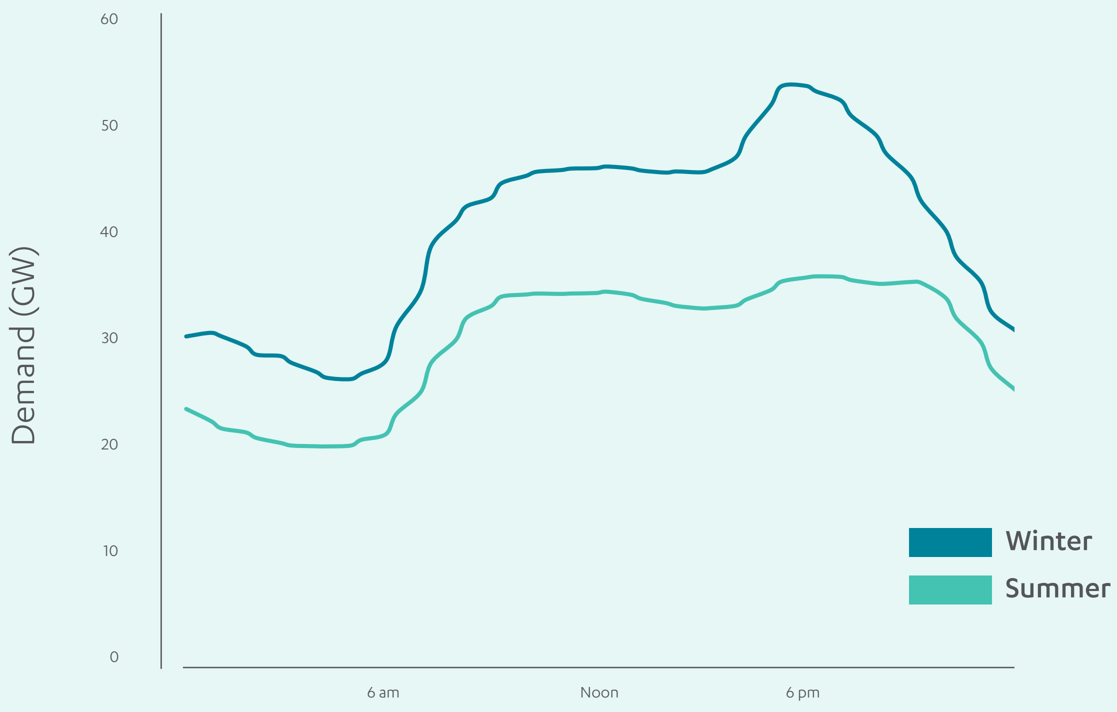
1.17 We also need to ensure there is enough electricity in the system to meet the needs of consumers at any given time. There is significant variation in demand between morning and evening, week days and weekends, at different times of year and even depending on events on television. The United Kingdom generates around 340 TWh of electricity each year,[5] with daily demand peaking at around 55-60 GW, typically just for a few hours on winter weekday evenings.[6]

1.18 As set out above, our electricity system has developed so that changes in demand are primarily balanced by increasing and decreasing supply; mostly from fossil fuel based sources of power. This means that there needs to be enough generation capacity to ensure this peak can be met when it occurs, with enough margin to ensure that there are sufficient supplies if some power stations are unavailable. This approach, whilst effective, results in our power stations being used at around 55% of their available capacity on average.[7]

1.19 With peak demand only occurring for a few hours each year, however, this means that a significant amount of generating capacity is required which may be rarely called upon. Since the costs to consumers of providing such capacity on a commercial basis would be expected to be extremely high, the government has established the capacity market through which it pays directly for capacity to be available at times of peak demand.

1.20 If as we transition more fully to low carbon sources of power, we continue to meet peak demand purely through increasing our supply rather than considering other approaches, the costs to consumers or taxpayers of building the necessary power stations and upgrading our networks will be higher still and increasingly hard to justify.

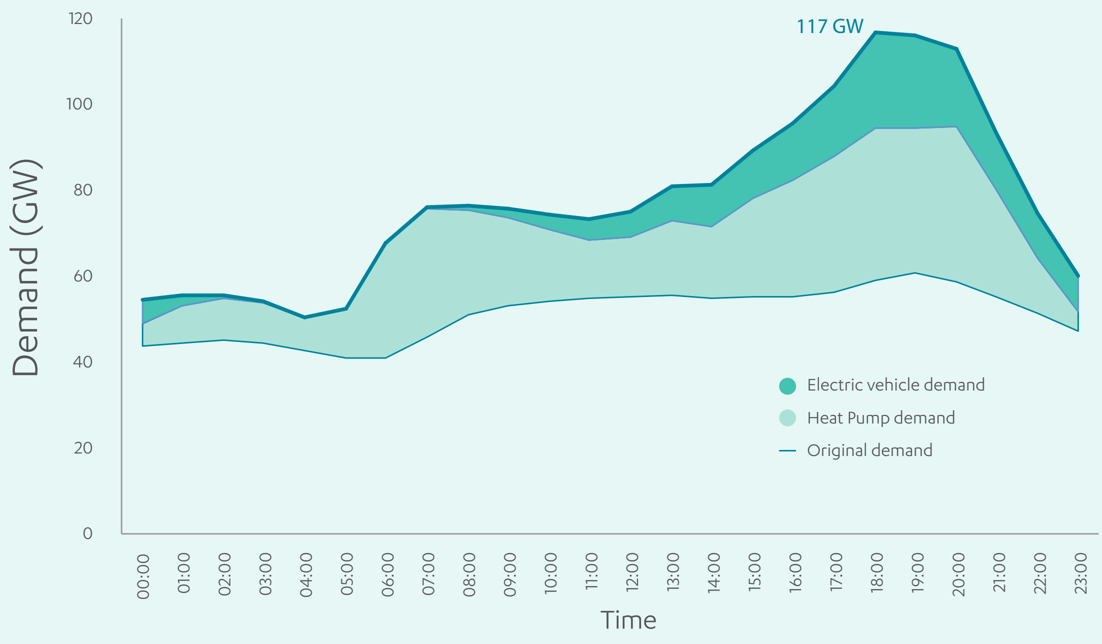
Great Britain electricity demand on a typical week day[8]



Demand for electricity is likely to change

1.21 Our demand for electricity is also likely to change through the rollout of electric vehicles, the decarbonisation of our heat supply, the introduction of smart technologies, and increased energy efficiency. This could lead to radical shifts in our patterns of electricity consumption. The need for electricity at peak times of the day could double, whilst the total amount of energy we use will only slightly increase.[9]

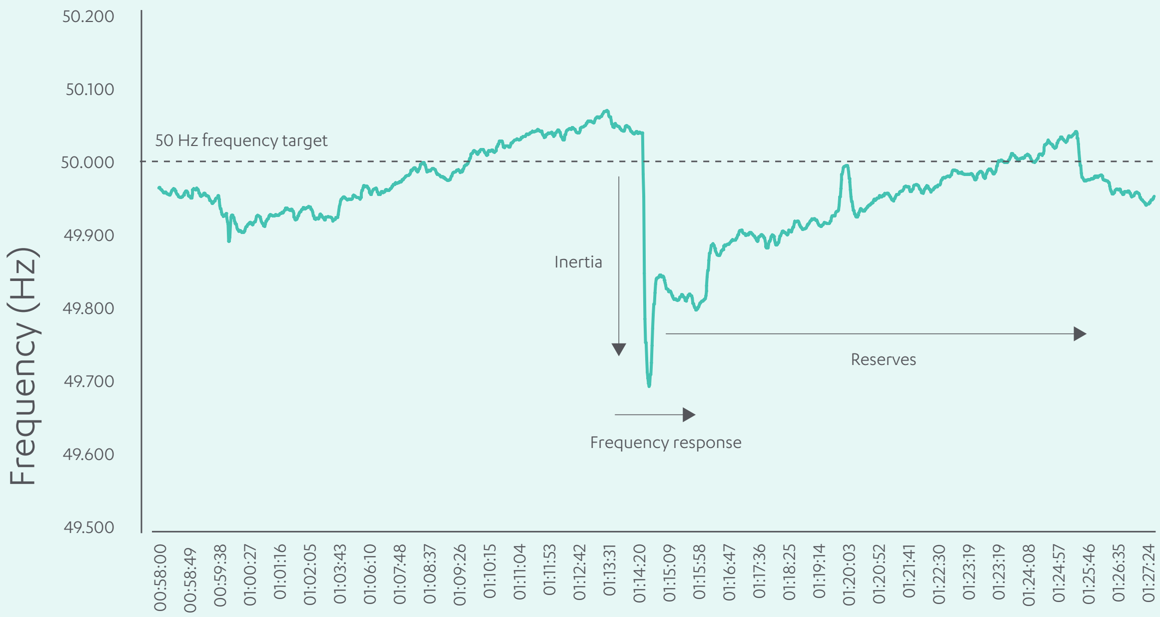
Possible future daily demand scenario with sub-optimal power system[10]



The network needs to be resilient to unexpected events

1.22 Finally, the electricity system also needs to be flexible enough to meet very rapid changes in demand and supply, for example due to a power station suddenly failing. This is the second part of the System Operator's role, which it fulfils by ensuring there is sufficient inertia in the power system to manage imbalances in the very short term (the first few minutes after a shock to the system) and by having sources of power (typically fossil fuel plants or hydro power stations) in reserve that can adjust their output quickly over the slightly longer term. The mechanism through which the System Operator procures these is known as the ancillary services market.

How the GB electricity system returns to balance after a sudden loss of supply[11]



1.23 As we switch to a more intermittent and less flexible low carbon generation mix, demand for these services is expected to multiply by up to ten times.[12] Continuing to use fossil fuelled power stations to provide the majority of these services which keep our system stable would require them to run part-loaded. This would be expensive, inefficient and limit the amount of low carbon power that the system can absorb.[13]

1.24 Procuring flexibility from other sources across the electricity markets would mean that the UK could build fewer new power stations, integrate more low carbon electricity at a lower cost and use all the assets in the electricity system more efficiently, leading to significant cost savings for consumers.

Different parts of the GB electricity market

The **wholesale market** is where 95% of electricity trades take place, up to 'Gate Closure' (one hour ahead of delivery).[14] It is where the majority of government intervention to support low carbon generation takes place – with power stations' revenues being 'topped-up' through the Contract for Difference or Renewables Obligation regimes on the basis of the output they sell into the wholesale market.

The **balancing market** operates from 'Gate Closure' through to real time and exists to ensure that supply and demand can be continuously matched. Participants submit 'offers' and/or 'bids', which represent the price the System Operator pays them to vary their generation or demand over that period. These costs are then passed on to those who were out of balance.

The System Operator also procures a number of **ancillary services** to help it manage the electricity system in case of unexpected shocks, such as the failure of a power system. Providers need to be able to meet a number of technical specifications around how quickly they can supply power and over what time period.

The **capacity market** was created to make sure that Great Britain has enough reliable sources of electricity in the wholesale and balancing markets at periods of peak demand. Participants are given a steady payment, even when they are not generating power, in return for being available to generate or reduce demand when needed.

1.25 The increasing costs associated with balancing the electricity system are not only related to generation capacity. They are also driven by the need for increased network capacity to move electricity efficiently around the country from power stations to consumers. In the same way that the amount of generation capacity we have is scaled to meet peak demand, the size of electricity network (in terms of the number and capacity of the cables) is also designed to meet the short periods of time when consumption and generation are at their highest. If the status quo continues, network reinforcements at the distribution level alone could cost up to £30bn from now to 2030.[15]

The long term challenge this represents is immense, but it also presents us with an enormous opportunity

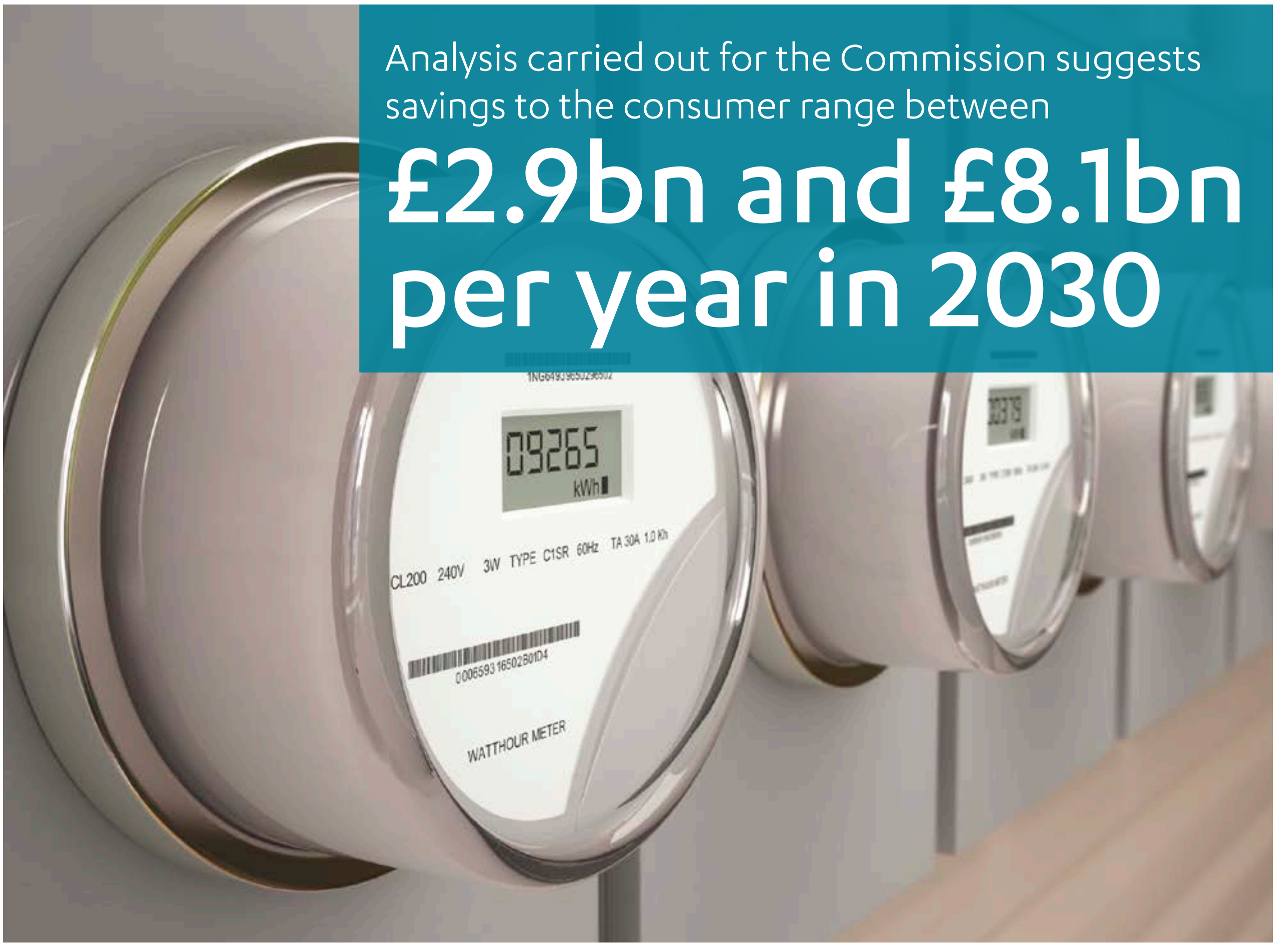
1.26 The dual challenge of ensuring that we continue to have enough power at times of high demand and meeting our carbon targets will require a huge amount of investment in infrastructure, not only in the power stations and renewable sources of power that generate electricity but also in the transmission and distribution networks that deliver it to industry, businesses and homes.

1.27 If we get this right, we have the opportunity to significantly reduce the amount we need to build, and therefore the cost of this transition, by placing new and alternative sources of flexibility at the heart of our electricity system and making efficient use of our assets.

The technologies are becoming available to allow us to meet these challenges

1.28 Flexibility can come from a selection of existing and emerging technologies. There is a large amount of untapped potential which could revolutionise the way we view and operate our system and result in lower costs. We need to ensure we unlock it, rather than replicating a system that was designed for a different age.

1.29 The benefits of creating a more flexible system are high, driven by avoided investment in expensive new generation whilst still decarbonising our system. Analysis carried out for the Commission suggests they range between £2.9bn and £8.1bn per year in 2030.[16] Even in scenarios where the UK does not meet its climate change objectives, increasing flexibility results in large savings. These results are based on the use of technologies which either exist today or are likely to be available by 2030.[17]



What can provide flexibility?

Flexibility in the electricity system is about generators and consumers changing their behaviours in response to signals (such as a change in price, or an electronic message) helping the whole system work more effectively.

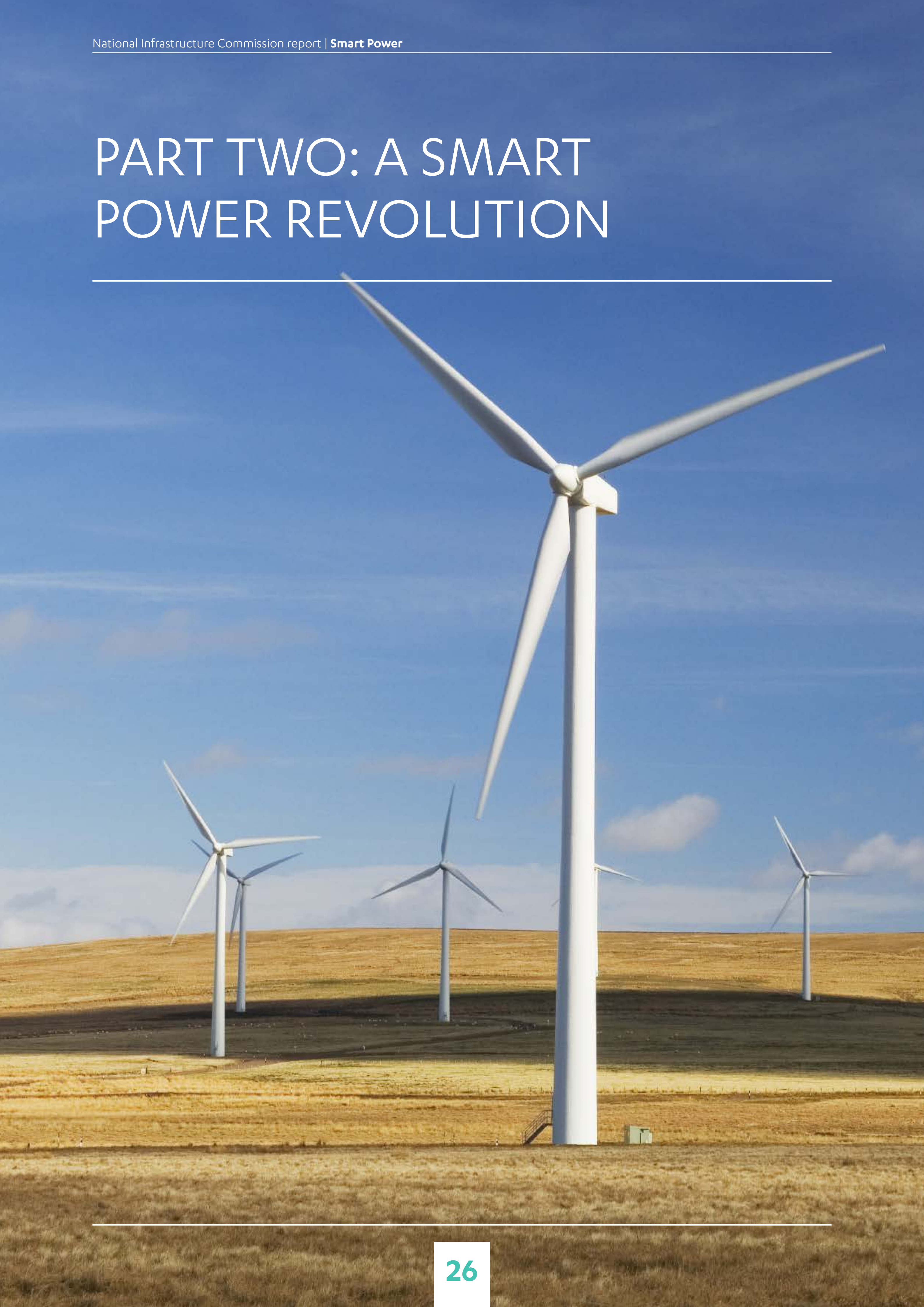
- **Demand flexibility** enables consumers to manage how and when they use electricity. By responding to changing prices throughout the day (i.e. lower prices when electricity is abundant, higher prices at times of peak demand) the peak demands on the system can be reduced. New technologies are enabling this be done with no compromise in the quality of service consumers receive or any reduction in businesses' output.
- **Storage** comes in a variety of forms and can fulfil multiple functions. For example, it can make the electricity system more robust to sudden changes, such as a power station failing, reduce the need to expensive upgrades to the electricity network and help integrate intermittent renewables such as wind and solar.
- **Interconnection** links the GB electricity market with those of other countries. This allows imports of power at times of peak demand, as well as the opportunity to export when electricity is abundant.
- **Flexible generation,** which is able to increase and decrease its output quickly and easily, can help meet changes in supply as the power from less controllable power stations (such as intermittent renewables) varies.
- **New network technologies** such as digital communications which can make our networks smarter and able to react to changes in real time.

1.30 In all scenarios, increasing the flexibility of the system is a low-regrets option and makes it easier for the UK to achieve its carbon targets at a lower cost. The key to achieving this will be to ensure that both our infrastructure and our regulatory frameworks are able to accommodate new sources of flexibility and enable them to secure a financial return for the services they provide to the system.

1.31 Many countries around the world are facing a similar set of challenges to the UK. However given the amount of capacity that is set to close over the next few years, the UK is uniquely placed to be a world leader in deploying innovative solutions to tackle them. The remainder of this report sets out how to make this happen.

1.32 **The Commission's central finding is that Smart Power – principally built around three innovations, Interconnection, Storage, and Demand Flexibility – could save consumers up to £8 billion a year by 2030, help the UK meet its 2050 carbon targets, and secure the UK's energy supply for generations.**

PART TWO: A SMART POWER REVOLUTION



2 A SMART POWER REVOLUTION

2.1 In the coming decades three exciting new technologies will continue to develop, which could play an important role in reducing the costs of balancing the energy system as we transition to lower-carbon sources of power. These are:

- Interconnection
- Storage
- Demand flexibility

2.2 The transformation that will be needed in how the UK generates electricity in the future means that the UK is uniquely placed to put these at the heart of its energy system – lowering emissions, improving efficiency and reducing bills.

Interconnection

Interconnection to overseas markets has an important role to play in any future electricity mix. The existing 'cap and floor' regulatory regime has started to bring forward a healthy pipeline of interconnection projects that will deliver significant benefits to British consumers.

However, there is the potential to do more and greater levels of interconnection could be of benefit. The level of benefit will depend on factors such as the amount of renewable capacity in the UK, the deployment of other sources of flexibility (such as storage) and how other European markets evolve.

We need to make sure that the UK's regulatory framework facilitates investment in greater capacity and encourages interconnectors to offer other flexibility services to the electricity market.

The role of interconnectors will evolve over time, driven by the precise makeup of the markets in the UK and abroad. Over the longer term, there is the potential for interconnectors to allow Great Britain to access low cost, low carbon power as well as the ability to export our renewable electricity at times when weather conditions drive high levels of generation.

2.3 Interconnection is the physical linking of electricity transmission systems across borders to allow the cross-border trading of electricity. As an island nation, the need to lay long subsea cables has meant Great Britain has historically had low levels of interconnection relative to other countries. It currently has 4 GW of interconnection capacity (around 5% of total generation) through four interconnectors – two to the island of Ireland, one to France and one to the Netherlands.[18]

The technical characteristics of interconnectors

Interconnectors are large transmission cables, often made predominantly of copper, which allow electricity from one country to flow to another. The flow of electricity is dictated by the price, with power flowing to the market which offers the best return. Interconnectors are generally considered to have a lifespan of around 40 years.

As with any large transmission network, interconnectors do suffer from certain losses. These have been calculated to be around 1.5% loss due to conversion and a transmission loss of 0.9% per 100km.[19]

The capital costs of interconnection depend primarily on its capacity and the length of the cable. As an indication, two projects have recently agreed construction contracts:

- NEMO, a 1 GW cable to Belgium (140 km), €500 million[20]
- North Sea Link, a 1.4 GW cable to Norway (740 km), €1.5 billion[21]

2.4 Interconnectors offer a number of benefits to Great Britain (GB) and are a key source of flexibility to the electricity system, with their ability to shift large volumes of electricity from where it isn't needed to where it is. This gives them the potential to reduce wholesale electricity costs and improve security of supply. They can also allow GB to access low carbon electricity at a low cost.

2.5 Interconnectors can be thought of as both additional generation capacity and power exporters. This is because they allow electricity to be imported at times of peak demand but are also able to sell electricity abroad when we have more than we need.

2.6 The former often reduces costs as power can be accessed to meet peaks in demand without needing to build expensive generating capacity. As set out below, different markets have peaks in demand and supply at different times of the year and different times of day, so GB's periods of highest demand may often coincide with points when the supply of electricity from other countries is plentiful and hence the costs are lower.

2.7 Being able to export electricity means that power stations in Great Britain can continue to generate even when domestic demand is low, increasing their profitability. This is particularly important for low carbon plant as they tend to be less flexible when they generate.

2.8 These effects mean that interconnectors have the ability to reduce costs and improve revenues in both of the connected countries. However, the flows on an interconnector at any point in time are driven by the relative prices in each market. Price differences between markets are driven by several different factors:

- **Differing generation mixes and energy policies:** Cost differentials can arise through different types of power station setting prices in different markets. For example, the GB market remains dominated by fossil fuel plant, which therefore sets the price for electricity. In some European countries, the price is driven more by the cost of renewable energy, which will rise and fall at different times from the GB price. Country-specific taxes such as the Carbon Price Support (CPS) in the UK can also drive price differences.

- **Different demand patterns:** Different countries have peak demand at different times of day. For example, the morning peak in the Netherlands tends to be two hours earlier than in Great Britain because of the time difference and the earlier start to the Dutch working day. This means an interconnector can export electricity from GB early in the day and import to meet the GB's peak.

- **Volatility in prices between countries:** There can be unpredictable differences in prices between markets, for example due to power stations being unavailable. In future, as technologies such as wind and solar generate a greater proportion of our electricity, weather patterns will play an increasing role in determining prices, increasing the level of volatility. Interconnection between countries with different weather systems can help to smooth out these effects.

2.9 There is a consensus that there has historically been a sub-optimal level of interconnection between the Great Britain and other markets, given the arbitrage opportunities that exist.[i] To address this, Ofgem recently introduced a 'cap and floor' mechanism which has proven to be successful in driving investment. A number of interconnector projects are being proposed by private investors, including links to Norway, Denmark and Belgium, as well as additional connections to France and Ireland.

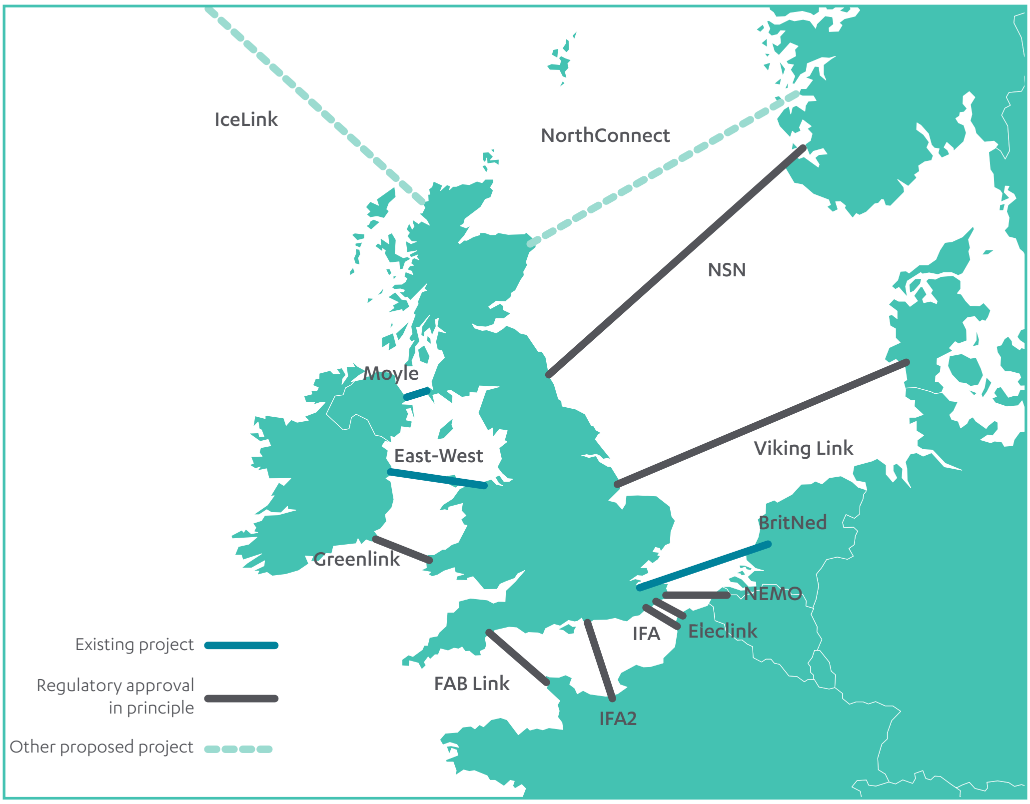
2.10 If all of these projects go ahead as currently planned then interconnection capacity will increase significantly to 11.3GW (more than 10% of GB capacity) by the early 2020s.[22]

If all projects go ahead as currently planned then interconnection capacity will increase significantly to more than 10% of GB capacity by the early 2020s

"Ofgem's development of the cap and floor regulatory model has been successful in helping to address barriers to additional interconnector investment – Energy UK[23]"

[i] This includes current interconnectors, projects which have received approval through Cap and Floor and those which have a regulatory exemption.

Existing interconnectors and the future pipeline



2.11 The Commission's evidence suggests that this pipeline of interconnectors will deliver significant net benefits to the UK. Analysis conducted by National Grid identifies the expected net benefits of 8-9 GW of interconnection to be equivalent to nearly £3m every day, from a reduction in the wholesale price of electricity.[24]

2.12 However, it is important to note that interconnection can result in winners and losers. Connecting to another market means that for some parts of the day, at times of relatively low domestic demand the ability to export energy increases the level of demand, meaning prices will be higher than they would have otherwise been (a cost to consumers but a benefit to generators). This is only occasionally an issue in Great Britain, as its interconnectors are used much more to import than to export energy. It is a more significant concern in countries expected to be net exporters such as Norway.

2.13 The degree to which exporting electricity over an interconnector changes wholesale prices depends on the specifics of the market and its generation mix. In some markets the additional generation required may come from more expensive generation, which would tend to increase the wholesale price in the exporting market. Other countries may have a surplus of relatively lower cost generation and the impact may be less pronounced.

2.14 Conversely, at period of high demand, the ability to increase supply by drawing upon other countries' generating capacity will drive costs down. While this may be of concern to the generation sector, and particularly investors in fossil fuelled power stations (as it is in these periods of high demand that they have typically been able to make the greatest profits), it will benefit consumers by reducing the costs overall.

2.15 Interconnection can also improve security of supply by providing the option of importing at times of stress when demand is likely to be highest and by increasing diversity by offering capacity from an entire market rather than a single power station.

2.16 However, some argue that additional interconnectors may reduce security of supply. This reflects the concern that they may displace some GB-based generation, but cannot be guaranteed to be available during periods of greatest stress on the system (for example, due to stress events happening simultaneously in both markets).

2.17 To deal with this, the capacity market 'de-rates' interconnectors when it calculates the contribution that they can make to our security of supply. It does this by applying a percentage reduction to the total capacity of the interconnector. This de-rating factor reflects the probability that market prices mean that the interconnector is importing to GB during a time of system stress. In the 2015 capacity auction, the de-rating factors used ranged between 6% and 69%, depending on the characteristics of the market being connected to.[25] The Commission believes that this adequately mitigates any risks to security of supply interconnectors may present.

Accessing low cost, low carbon electricity

2.18 Linking European electricity markets through interconnection can also enable low carbon sources of electricity, particularly renewable electricity, to be deployed at a lower cost. It allows renewables projects to be sited where they are best suited, for example offshore wind in the North Sea and solar power in Southern Europe, with the electricity exported to where it is most needed.

2.19 Recent analysis suggested that by locating renewables where they would operate most efficiently it would be possible to achieve the same overall level of renewable output using 15% less capacity and that the benefits across Europe could exceed €200bn by 2030.[26] In Great Britain this approach could allow for the export of renewables in future at times of surplus rather than the need to pay to curtail generation. The same approach could be used to import low carbon power from other countries where the costs of deployment are significantly lower than those in GB. One example of where this approach is already being considered is through interconnection to Iceland.

Connecting to Iceland

Iceland has abundant natural energy resources and has exploited these to produce an almost entirely renewable electricity system. Their system is 71% hydro-power and 29% geothermal.[27] As these technologies have no fuel costs, this has led to Iceland having one of the lowest costs of electricity in the world.

The benefits of connecting the GB and Icelandic electricity system would include:

- Increased security of supply for both countries.
- GB would benefit from reliable imports of potentially flexible low-carbon generation.
- Potential to reduce GB consumer bills if the cost is lower than comparable alternative sources of electricity.
- Iceland would benefit from a larger market allowing generators to invest in new generation.

In light of these benefits, in November 2015, the Prime Ministers of both countries agreed to set up a taskforce to consider the potential for this project.

Most interconnectors make their business case by exploiting the price differential in two freely traded markets. By contrast, Iceland does not have a freely traded market and electricity is sold through bilaterally negotiated, long-term contracts.

The Icelandic energy network is also very small compared to the GB system, or any of the other systems in Scandinavia or mainland Europe, and there is not sufficient surplus capacity to provide sufficient electricity for an interconnector. Iceland currently has around 2.8GW of installed capacity and a peak demand of around 2.5GW. There is the technical potential to significantly increase the capacity of Icelandic electricity production which could produce sufficient additional power to export, although this would need to take into account environmental factors associated with developing new generation in Iceland's delicate environment.

These factors mean that the overall project is likely to require a package of new generation along with the interconnector. This is significantly different from a typical interconnector, and exposes the project as a whole to a different set of risks, which means that existing regulatory mechanisms may not provide the appropriate support.

The need for more interconnectors

2.20 Given the uncertainty around the factors which will drive interconnection benefits, it is difficult to set out a precise future optimal level of interconnection that Great Britain should target over the long term.

2.21 In a scenario where the future GB electricity system has a significant proportion of intermittent renewables and other low carbon generation, combined with larger differences between minimum and maximum demand (for example due to the electrification of heat), the opportunities and benefits from interconnection will increase. The ability of interconnectors to offer services into the ancillary services market, such as frequency response, would also increase the case for additional capacity.

2.22 However, in a scenario with a significant share of flexible generation, consumers more actively managing demand, and low cost access to storage, the same level of additional interconnection may not provide value to the economy.

2.23 It is important also to note that not all interconnectors between markets are the same and it is likely that whilst additional links to some markets will add significant value, others may not achieve the same benefits. Markets that have relatively little existing connection to GB, with significantly different electricity prices and patterns of demand, offer the greatest potential to reduce costs and improve efficiency through increased interconnection. The Norwegian electricity market, for example, has many of these characteristics along with flexible, low carbon, hydropower stations, which can counter the expected increase in intermittent generation in GB.

Recommendation 1: Government should pursue additional interconnectors with other European countries where the benefits are most significant.

Interconnection investment decisions should continue to sit primarily with the private sector but there is a role for government-led diplomacy to unlock those markets that can offer potentially large benefits to UK consumers. The government should therefore focus its efforts on exploring increased interconnection to markets with abundant sources of flexible low carbon electricity, such as Norway and Iceland.

Storage

Storage allows consumers and suppliers to take energy from the grid or a generator and store it so that it can be used when it is most needed.

Electricity has historically been difficult and expensive to store. The UK's current main source of storage is pumped hydro, for which water is pumped upwards into reservoirs from where it can be released to generate power.

However, the last decade has seen a great deal of innovation, and there is now an increasing range of other ways to store energy including chemical batteries, compressed air and supercapacitors. Much of this innovation has been driven by consumer electronics and investment in electric vehicles. This has rapidly reduced costs: for example, the cost of lithium ion batteries has decreased from more than $3,000/kWh in 1990 to less than $200/kWh today.[28]

Storage technology is now on the verge of being able to compete with power stations for some of the services they provide. Crucially, it will not need subsidy to be attractive to investors, but it does need changes to the existing electricity market frameworks.

When our electricity markets were designed these technologies did not exist. The result is a market that is opaque, closed to storage technology, and regulated in a way that often disadvantages storage providers. This makes it harder for them to establish a viable business model, as they are unable to participate across the various electricity markets in the same way as generators.

In this way, barriers to the market are preventing a technology from being effectively deployed that could increase the resilience of the electricity system, prevent the need for additional power stations and help secure the power mix needed to hit our legally binding climate change targets.

The benefits of storage could be substantial. It can help reduce the impact of peak demand, provide an outlet for power stations at other times of day, and ease constraints on our grids.

Network owners are only just starting to make use of storage technologies. There is now enormous potential to make storage technologies an integral part of our networks. Network owners should be encouraged to see storage as a central tool to improve the capacity and resilience of their networks as part of a more actively managed system.

The UK should become a world leader in electricity storage systems. We can achieve that, not through subsidies, but simply by ensuring that better regulation creates an equal playing field, to unlock its full potential.

2.24 Electricity storage can play a key part in delivering a flexible electricity system. Traditionally, Great Britain has principally relied upon the ability to generate more electricity as and when it is needed, with the energy stored in the form of fossil fuels. To date there has been relatively little dedicated storage, with the vast majority, about 3,000 MW of capacity, provided by large scale pumped hydroelectric power stations in North Wales and Scotland connected to the transmission network.[29] These play a crucial role in the immediate short term management of sudden spikes in demand and unexpected losses of capacity, but they cannot contribute to managing more localised patterns of demand. In the future a wide range of storage technologies deployed at every level from the large scale through to households could help deliver the flexibility we need. If costs continue to fall, up to 15,000 MW could be economically deployed by 2030.[30]

2.25 Developments in electricity storage have the ability to radically change the electricity system. A recent report by Energy UK (the largest trade association for the energy industry) looking at the development of the sector stated that 'electricity storage is widely regarded to be the single most important technological breakthrough likely to happen over the period to 2030 and a complete 'game changer' in the way that the power system operates'.[31]

2.26 It is important to recognise that electricity storage is not one single technology, but a diverse range including batteries, pumped hydropower and supercapacitors. This allows storage to play more than one role in increasing the flexibility and robustness of the electricity system, including:

- Making the system more resilient to short term imbalances in demand and supply and allowing the integration of a larger share of renewables in the generation mix.
- Enabling network owners to increase the capacity of their networks more cost effectively than simply building additional cables.
- Allowing customers (including households, businesses and electricity suppliers) to manage their usage more actively, taking and storing electricity at times of low demand and prices and then using it at peak times, which both reduces costs and helps to balance production and demand.

2.27 Making effective use of storage will strengthen network capacity and minimise the need to build new power stations that only operate for a few hours each day when demand peaks. It can also provide a source of demand for electricity at times when intermittent generation (e.g. wind and solar power) is generating but demand would otherwise be low. This increases the profitability of renewables, reducing their need for subsidy and their cost to consumers. The variety of technologies available also means that storage can be deployed at a range of scales and locations from large scale storage connected to the national transmission network to small batteries in people's homes.

Types of energy storage

Pumped Hydropower – this is the most mature of all the storage technologies and widely deployed around the world. Energy is stored by pumping water up to a reservoir to be released when needed, generating electricity through hydro-electric turbines. Relatively large amounts of energy can be stored, determined by the sized of the reservoirs.

Compressed Air Energy Storage (CAES) – air is compressed and stored under pressure either in underground caverns or in above ground vessels. The air can then be released to drive a turbine and generate electricity.

Liquid Air Storage – similar to CAES, air is liquefied and stored in vessels. It can then be evaporated to drive a turbine and generate electricity.

Solid State Batteries – a range of electrochemical storage solutions. Lithium ion batteries are one of the key battery technologies, with deployment and cost reductions having been driven by their use in consumer electronics and electric vehicles. Sodium sulphur batteries are also being explored for commercial deployment.

Flow Batteries - batteries where the energy is stored directly in the chemicals making up the electrolyte solution.

Thermal – principally using heat and cold to store energy as a form of demand side response. However, various other applications allow electricity to be generated from stored heat.

Flywheels – energy is stored by rapidly spinning a rotor using an electric motor. The rotor can then be slowed, with the motor acting as a generator. Flywheels are starting to be deployed in grid applications, especially as they can respond to system needs very quickly.

Supercapacitors – these can store relatively large amounts of electricity which can be released in a short amount of time. Like flywheels, they are able to respond to the needs of the system very quickly.

Supporting the stability of the grid and increased renewables deployment

2.28 A key role for storage technology will be to provide some of the grid stability services needed to keep the electricity system resilient to unexpected events, such as a power station failing. Pumped hydro storage is already a key provider of this type of service. Batteries and other storage technologies are also ideally suited to play this role as they can dispatch power extremely quickly, precisely matching the needs of the system. Battery technologies are already more effective than using existing power stations for some of these services, demand for which will grow as the electricity generation mix develops and an increasing share of generation comes from intermittent renewables such as wind and solar power.

"Primary frequency response requirement [a type of ancillary service] could increase by 30-40% in the next 5 years, and by 2030 the response requirement will be between 3 and 4 times today's level."[32]

2.29 These challenges are already apparent in Ireland, whose Single Electricity Market is experiencing periods when around 50% of generation comes from renewables.[33] At this point, some renewable generation needs to be curtailed in order to maintain system stability, as there is a limit to the extent to which generation from fossil fuel plants can be switched off without affecting their ability to provide sufficient back-up. To deal with this, Ireland is starting to develop new ancillary services to bring forward new technologies, including storage, to maintain system stability with a lower level of continuing generation from fossil-fuelled plants. One such technology is the Kilroot battery, described in the box below, which can provide up to 20MW of flexible power to manage sudden changes in demand. With solutions like this, Ireland is seeking to achieve the goal of being able to manage periods where up to 75% of its generation comes from renewables.[34]

The Kilroot Battery

In January of this year AES UK & Ireland announced the completion of the first UK transmission scale battery storage facility in the UK. The 'Kilroot Advancion® Energy Storage Array' is based in Carrickfergus in Northern Ireland and offers 10 MW of interconnected energy storage, equivalent to 20 MW flexible resource. This storage – which is comprised of over 53,000 batteries – is able to respond to changes in the grid in less than a second, providing a very fast response ancillary service to help balance the electricity system at times of high demand. The array is a fully commercial project, with no additional costs for consumers.

This 10 MW array represents the first step towards a planned 100 MW energy storage array at the same location. If completed, this much larger array has been estimated to provide £8.5m in system savings and the equivalent of 123,000 tonnes of CO_2 eliminated per year, by displacing fossil fuel generation for peaking and balancing requirements, and facilitating fuller integration of existing renewables.

The potential benefits of this project are being closely monitored by the System Operator Northern Ireland (SONI). Robin McCormick, General Manager of SONI explains: "Integrating battery storage solutions onto the system is an important development which should bring real benefits to customers across the island. As the transmission system operator, this innovation provides a significant learning opportunity; we will assess the role that battery storage will play in the increasingly diverse portfolio of generation sources."

2.30 Whilst Great Britain does not yet have the same share of renewables as Ireland, some future scenarios have levels of renewables that would result in similar issues.

2.31 For this reason, National Grid, in its role as System Operator, has taken some steps to increase the range of technologies able to participate in its ancillary services market. In particular, it recently tendered for 200 MW of Enhanced Frequency Response (EFR) capacity – technologies that can supply power to the network in less than a second – to better balance the electricity system, on the basis that batteries (and interconnectors) have the ability to offer these services. This tender received expressions of interest totaling more than 1.3 GW of capacity from over 65 projects.[35] This is clear evidence that there is a strong appetite from storage providers to deliver system services, although as set out in Part 3 of this report, changes to the operation of the UK's distribution networks will be needed to make the most effective use of these technologies.

2.32 Tendering for new types of ancillary service in this way is helping to support the deployment of new battery and other technologies. At the moment, revenues from ancillary service contracts form the central part of the investment cases for lithium ion battery projects. However, these tenders remain a marginal element of the overall market, and without more widespread opportunities to tender and a level playing field, it is difficult for potential storage investors to develop business cases and access finance for their projects. The barriers to storage technologies participating more fully in the ancillary services market are discussed in paragraphs 2.49-2.51 below.

Mitigating the need for expensive network upgrades

2.33 Another important role storage technologies can play in the electricity system is to offer a cheaper way of ensuring that our networks, both at the national and local level, are able to deal with peaks and troughs in the flow of electricity.

2.34 Like other parts of the electricity system, the transmission and distribution networks are set up to meet relatively short periods of peak demand and supply. Capacity constraints have been managed by either reinforcing the network by building more cables, paying power stations to prevent them from exporting to the electricity network – known as 'constraining off' – or preventing sources of demand and supply connecting until the network has been strengthened.

2.35 Building new cables to reinforce the network to meet a level of demand it might face for just a few hours of the day or year is expensive when compared to the benefits it delivers. This is why it is often more cost effective to pay some power stations not to generate for short periods of time.

2.36 Having storage connected to the system means that instead of exporting power on to the network when it is suffering from constraints, generators can instead store the power, for example by compressing air, creating heat or charging batteries. This energy can be released at a later time when the grid is no longer constrained, avoiding the need to lay more cables. The same approach can be used for sources of demand; consumers can store the power they need when there is significant grid capacity and prices are low, avoiding the need to draw on the network later in the day.

2.37 The UK's electricity networks, both at the transmission and distribution level, vary substantially in terms of their age, design and the types of load they must accommodate. For this reason, different types and scales of storage will likely be needed.

2.38 Some network owners have already started to invest in storage (for example, the Leighton Buzzard battery described in the box below) as a way to defer or avoid investments and better manage their networks. Given the nascent state of storage technologies, these investments have been supported through Ofgem's Low Carbon Network Fund (LCNF), with the findings from these investments being shared with other network owners and the wider industry. But these investments remain small-scale and few in number. More widespread roll-out will be needed to fully realise the network benefits of storage technologies, which will require a number of regulatory and market barriers to be tackled, as set out below.

The 'Big Battery' in Leighton Buzzard

The UK Power Networks substation in Leighton Buzzard, Bedfordshire, has been in need of reinforcement over recent years due to capacity constraints. In other words, local electricity demand has at times been higher than the level that the substation could supply, for example during periods of cold weather.

To address this UK Power Networks looked to the possibilities of electricity storage and in 2013 it was awarded £13.2m from Ofgem's Low Carbon Network Fund to add to its own £4m funding to push forward the Smarter Network Storage project (SNS). This scheme features a 6MW/10MWh storage solution comprising approximately 50,000 lithium ion batteries, which has enabled UK Power Networks to manage electricity demand at peak times without building excess capacity. By charging during the day, the Big Battery stores electricity that can then be dispatched in the evening when residential customers in Leighton Buzzard need it. During low or average electricity demand times, the storage capacity of the Big Battery is enough to power about 1,100 UK homes for a whole day or over 27,000 homes for one hour.

UK Power Networks is now using SNS to explore ways to maximise the value from storage by offering multiple benefits to both network operators and the wider UK electricity system. It is the first storage solution of its kind to be commissioned in the UK and the first large scale battery to support National Grid. To date SNS has offered over 2,900 hours of transmission network services and has exported electricity to the distribution network at periods of high demand on more than 120 occasions.

Suleman Alli, Strategy, Safety and Services Director at UKPN said "Our 'Big Battery' in Leighton Buzzard is the first grid-scale storage of its kind, providing clarity to DNOs and the industry of the real opportunities of this technology as well as identifying the barriers preventing its wider uptake."

Managing power usage to deal with periods of peak supply and demand

2.39 The third role energy storage can play in increasing flexibility is by providing a source of electricity supply at times of peak demand and a source of demand when otherwise surplus electricity is being generated. In this way it is similar to both interconnectors and demand flexibility. Owners of storage technologies can arbitrage between periods of low prices and high prices – buying power when prices are low and storing it, so that it can be sold at a competitive price when the costs of generated capacity are higher – as a means of creating revenues and cutting costs for consumers through greater price competition for power to meet periods of peak demand.

2.40 Like other forms of flexibility, this enables storage technology to reduce the need to build conventional power stations that only operate to meet short periods of peak demand, which will also save consumers money through lower capital expenditure.

2.41 The greatest investment case for electricity storage being used in this way lies where it can charge and then discharge electricity over relatively short periods of time. This approach means that the storage capacity needed remains relatively small, reducing the capital cost of investment, and that revenues can be generated over a large number of charging/discharging cycles, meaning that the price difference between charging and discharging can also be smaller. Analysis by Imperial College indicates that electricity storage over longer durations adds little additional commercial value.[36]

2.42 There is also increasing potential for storage to be deployed in people's homes, especially as part of a smart household network. There are a number of providers of domestic scale storage, from companies such as Tesla and Moixa. DECC are currently supporting a demonstration project deploying domestic scale storage in around 250 sites to evaluate the role it can play in reducing peak demand, and how through aggregation, small scale storage can offer services to the network. At the moment deployment of storage at this scale makes most sense where it is linked to onsite power generation such as rooftop solar panels, making sure a household is able to use a larger share of the electricity it generates and reducing bills. As costs of storage fall and with the roll-out of smart meters and time of use tariffs it is likely that storage at the household level will become increasingly attractive.

2.43 In a future scenario with a significant share of the generation mix coming from intermittent sources, there will be increasing opportunities for storage to balance relatively short term differences in demand and supply. However, while effective deployment of storage technologies can significantly reduce the need for generating capacity to meet peak demand, it is not the case, particularly in the near term, that storage will eliminate the need for flexible forms of electricity generation (including gas fired plants) entirely. In particular, it will be necessary to ensure that there is sufficient capacity to provide security of supply when there is little wind or sunshine for a prolonged period. Analysis by the Energy Research

Partnership suggests that 'neither storage nor demand side management seem to be credible solutions to the security of supply issue caused by lulls in renewable output lasting 2-3 weeks'.[37] Managing a long period of insufficient generation through storage could require each household to have around 300 kWh of storage, equivalent to approximately 15 electric vehicles, which is unlikely to be a deliverable or cost-effective solution.[38]

Regulatory barriers to deployment of storage

2.44 As set out above, storage has the ability to offer valuable services to the electricity system. The increasing value of these services as our electricity system evolves combined with the falling costs of storage technologies mean that there is not a case for driving deployment through subsidies. However, a theme of many of the Commission's Call for Evidence responses was that resolving a number of regulatory barriers is the key factor in allowing storage to be deployed to its full potential.

2.45 The current electricity market regulations do not recognise storage as a distinct activity, but instead treat it as a form of generation and consumption. This approach ignores the other benefits that storage can play in the electricity system and creates barriers to investment in storage assets. For example, it increases costs for storage asset owners by requiring storage to be charged twice for using the electricity network – once as a generator when exporting electricity and again as a consumer when electricity is being taken from the network to be stored. Whilst storage technologies are clearly making use of the network both as a consumer and producer, charging in this way takes no account of the fact that storage assets are likely to be exporting power at times of peak load, and drawing power at times of peak generation, reducing the stresses faced by the network rather than increasing them.

2.46 Storage assets also face 'double charging' for the various government levies that are added to electricity costs, such as the Contract for Difference and Feed-in tariff schemes. These taxes are placed on the electricity used to charge-up the store and again to consumers when the electricity is exported. A better approach would be to charge these levies on the basis of the electricity actually used, reflecting that no storage technology is 100% efficient, rather than on both inflows and outflows. Not only would this be a fairer treatment, creating a level playing field with other technologies, but it would also incentivise more efficient storage technologies.

2.47 Storage's definition as a generation asset also makes it difficult for network owners, who have the best information where storage could provide value, to deploy it effectively. This is due to strict 'unbundling' regulations designed to allow equal access to networks. Whilst the Commission accepts that network owners should not be the owners of large storage assets, the regulations and associated contractual arrangements need to allow network owners to buy services from storage assets where appropriate.

Barriers to developing an investment case for storage

2.48 The complicated nature of storage, which could play a number of different roles in the electricity system and get revenues from each, means that it can be difficult for storage providers to develop a business case which relies on the stacking of these revenues.

2.49 Contracts to provide ancillary services underpin much of the current pipeline of storage projects. The nature of these contracts – in particular the fact that it is necessarily uncertain when a service might be called upon – presents challenges for storage owners in accessing the sources of revenue that would support their investments. In contrast, generators are able to provide ancillary services as a secondary element of their business model, with the primary source of revenues being the longer term and more secure contracts offered through the wholesale market.

2.50 This reflects the fact that the ancillary services market was designed when there was a limited need for flexibility, which could easily be delivered by large generators as a small additional service rather than as the core rationale for investment. As a result, many flexibility services (such as fast reserve)[ii] are procured through bilateral contracts between the System Operator and major generating companies with little transparency about prices or potential revenues. Without this information it is difficult for new developers to determine whether an investment in storage, or other emerging technologies such as demand flexibility, to deliver ancillary services would be worthwhile.

2.51 Increased tendering for ancillary services by the System Operator, with price information set out in market reports, has helped to make the market clearer for participants. Work has also started to make service contracts more open, allowing a single storage asset to target revenues across a number of roles (e.g. offering both network improvements and ancillary services). This work, accompanied by a number of pilots, has enabled progress to be made in developing business models and contracts that address some of these issues, but broader changes to the ancillary services market will be needed to enable more widespread and efficient deployment of these technologies and to allow storage investors to optimise where their assets are best used at each point in time. Because the need for flexibility will increase significantly in future, identifying and implementing those broader changes must be considered a priority.

Recommendation 2: The UK should become a world leader in electricity storage systems. Two steps are required:

a) DECC and Ofgem should review the regulatory and legal status of storage to remove outdated barriers and to enable storage to compete fairly with generation across the various interlinked electricity markets. The reforms should be proposed by Spring 2017 and implemented as soon as possible thereafter.

[ii] Fast reserve provides the rapid and reliable delivery of power through an increased output from generation or a reduction in consumption from demand sources, allowing the system operator to manage the frequency on the grid – for example in the event of a power station failing, providers of fast reserve must be available with 2 minutes of being called upon and able to deliver power for 15 minutes.

b) **Network owners should be incentivised by Ofgem to use storage (and other sources of flexibility) to improve the capacity and resilience of their networks as part of a more actively managed system.**

Demand flexibility

Demand flexibility can allow families and businesses to change how they use electricity. Deploying automated systems to reduce consumption at times of high demand and high prices and increase it at times of low demand, will allow consumers to save money and cut emissions without inconvenience.

In addition, demand flexibility can support the integration of low carbon generation. Flexibility in how we consume energy lowers the need for flexibility in supply, supporting the integration of inflexible low carbon generation such as wind, solar or nuclear.

Demand flexibility is commonplace in other countries, such as Australia and the US, and new technologies in this area are advancing. But it is currently underused in the UK.

Some of the best British businesses are already making use of flexible power, but there is potential for much wider take up. With the roll out of smart meters in every home in the 2020s, the domestic market for flexible demand could be significant. However, without tackling regulatory and cultural barriers, it is unlikely that the full benefits offered by demand flexibility will be achieved.

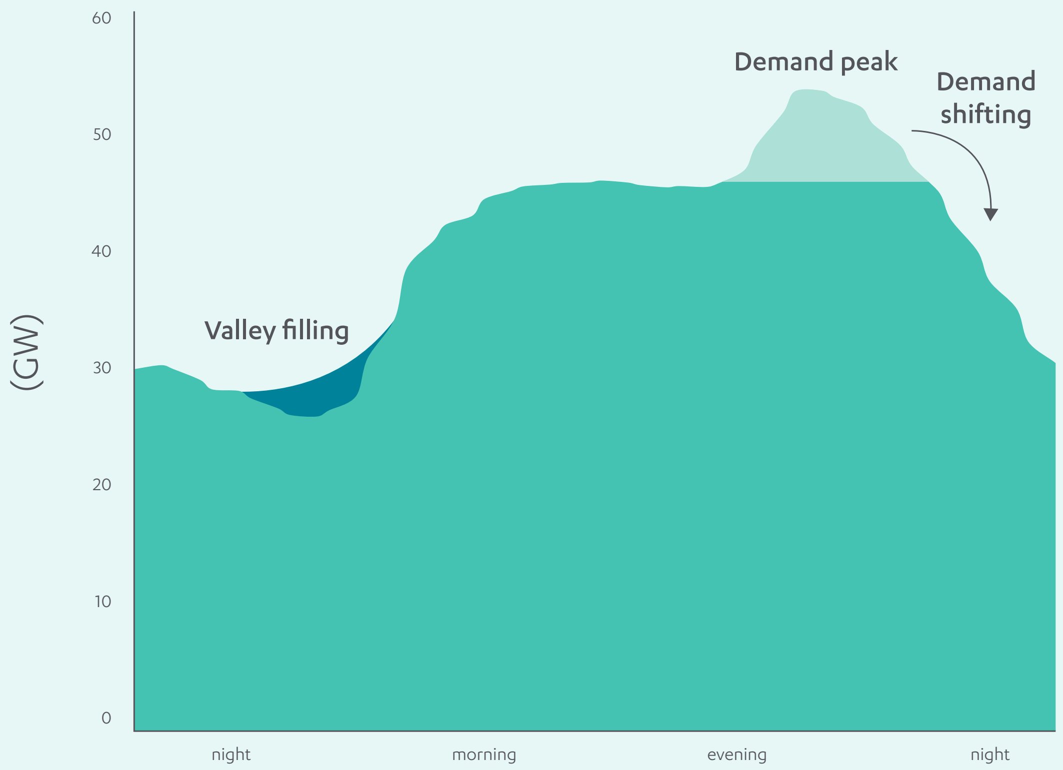
There is an opportunity here for UK firms. We are a world leader in the data analytics and software development that can be used to manage energy demand seamlessly: showing what can be achieved will enable these capabilities to be marketed to the world.

2.52 Demand flexibility is more commonly referred to as "demand side response". It covers a broad range of activities that can be undertaken to reduce or shift demand for electricity during peak periods, including adjusting the consumption of electrical appliances or other facilities or deploying off-grid sources of power.

2.53 These measures may only have a small impact at the individual level, but when aggregated together the effects can be significant. Providers of flexible power can use automated systems and data analytics to achieve this aggregation and deliver a significant reduction in demand on the distribution or transmission networks, as an alternative to increasing supply. This marks a significant break with the UK's historical approach which treats demand purely as something to be forecast and met, rather than controlled.

2.54 Definitions of demand flexibility vary. Some include purpose-built generation on the distribution network, as this can be used to manage demand on the transmission network. Other definitions restrict it to the

The effects of demand flexibility on the typical UK demand profile



use of assets that which not originally built to help manage the system but can still play a role. This could include a backup generator built for a factory, but not a generator built for the primary purpose of supplying the grid. This report uses the latter definition.[iii] In all cases, the definition also includes tools and incentives to reduce or reschedule energy usage by consumers at times of peak demand.

2.55 By consuming electricity more flexibly, the overall demands on the system are reduced. If some of the electricity used at peak times can be shifted to other parts of the day, then less generation capacity needs to be built. If the System Operator can procure capacity and services from the demand side, rather than from generators, then it can integrate more low carbon power on to the system cost effectively.[39]

2.56 Demand flexibility saves businesses and households money by reducing the investment needed in generation and network capacity, which is ultimately paid for by consumers. It also creates the opportunity to save money through purchasing the cheaper electricity at off-peak times. The commercial sector already benefits from these savings, and they will soon become available to domestic customers with the roll out of smart meters and smart tariffs (which vary by time of day).[iv]

If 5%
of current peak demand was met by demand side solutions

The system would be **£200 million** a year cheaper to run

It would be equivalent to the generation of a new nuclear power station[40]

Consumers could benefit by **£790 million**

[iii] Therefore for our purposes, new diesel farms being built under the capacity market should not be classed as demand-side response.

[iv] Domestic users can already benefit to some degree through the use of Economy 7 tariffs, but smart meters will allow much more sophisticated pricing mechanisms to be developed, increasing the scope for cost savings.

2.57 The range of activities included under the umbrella of demand flexibility is comparable to the range of storage technologies that exist. Flexible demand can be used to balance electricity demand and supply over a range of timescales, from very short term grid stability requirements to managing longer periods of peak usage. It can also help network operators to manage local constraints. Suppliers can use flexible power to manage their own portfolios and help control costs for their customers.[41]

2.58 The USA has led the way on deploying demand flexibility, where in some of its regional markets it can meet up to 15% of peak demand (the average is 6%).[42] The most cited example is the Pennsylvania, Massachusetts and New Jersey electricity market, where market arrangements have evolved over time to allow different demand side solutions to be rewarded for the services they can provide. This has led to a reduction of the average wholesale price of between 5-8% and a much larger reduction of peak wholesale prices.[43]

2.59 However, full scale demand flexibility is still in development in the UK.[44]

The USA has led the way on deploying deploying demand flexibility, where in some of its regional markets it can meet up to **15%** of peak demand

“So far we have only scratched the surface in terms of using available assets. This must be expanded, eventually giving the demand side an equal footing to the supply side. Otherwise the best options will not be selected, nor the best solutions implemented. Costs certainly will not be minimised, especially in the longer term
– Dunelm Energy”

2.60 It is difficult to estimate what level of demand flexibility exists in the UK, but it is thought to be significantly less than 1% of peak demand.[45] A recent Government-commissioned study concluded that there is significant additional demand side potential in many areas.[46] The sources of this are set out below.

Where does the potential for demand flexibility come from?[47]

Industrial and commercial consumers – back up generation	This refers to use of pre-existing emergency back up generators to switch on and reduce the amount of power required from the national grid.
Industrial and commercial consumers -demand-led	Industrial and commercial customers can reduce or shift their demand (for example power consumed for heat, refrigeration, ventilation and air conditioning).
Domestic demand-led	Domestic customers may be able to shift or reduce their demand (for example, altering the time at which storage heaters are charged, or postponing the charging of electric vehicles).
Smart grid technologies	Electrical energy storage and voltage control systems are being investigated by network owners for network management purposes, and can also have wider flexible applications.

2.61 Great Britain was one of the first countries in Europe to open up several of its markets to demand flexibility and the System Operator, National Grid, already procures a limited number of services from demand side providers, who are either large industrial consumers, or third party 'aggregators'. The latter coordinate groups of end users who are able individually to offer only small amounts of demand flexibility, combining these into more substantial reductions in demand which they can sell to the system operator or local networks. Aggregators cover the risk of not delivering this flexibility and therefore provide security to both buyers and consumers.

Saving Time money

Time Inc. is a leading publisher of print and digital magazine content, creating content for multiple platforms. Since 2010, they have participated in Demand Side Response (DSR) by reducing energy consumption in their London headquarters.

Time Inc. UK, working closely with Kiwi Power as their aggregator, identified chillers and air handling units as the appropriate non-essential assets for taking part in DSR. It allowed the building management system at a push of a single button to turn off two chillers completely and turn down the two heat pumps in the timeframe required by National Grid to reduce the load on the electricity system. The designed system and operation was tested to achieve the optimum energy saving with minimal disruption to staff. As part of the new installation to ensure more accurate monitoring and quicker response, a minute by minute meter is used to get real time readings which feed back into National Grid.

As a result of participating in DSR as well as other green initiatives, Time Inc. achieved over 10% energy saving between 2011 and 2013. Tony Floyde, the Facility Manager of Time Inc. UK said: "We consider our energy efficiency and integration into the National Grid's Short Term Operating Reserve programme with Kiwi Power to be very successful."

2.62 While this represents a positive step forward, National Grid has nonetheless acknowledged the need for 'greater access to services from the demand side'[48] and has stated its intention to increase its use of demand flexibility substantially by 2030.[49] In support of this, it launched a well-received campaign in 2015 called "Power Responsive" which seeks to enable businesses, suppliers and policy makers to shape the growth of demand flexibility collaboratively.

"The launch of National Grid's Power Responsive campaign in 2015 was a positive step."[50]

2.63 Other stakeholders have also recognised the considerable benefits that harnessing more flexibility on the demand side could bring.

"We see a very large potential for demand response to provide cost-effective balancing services to the network enabled by new technologies such as sensor and communications developments, digital trading and aggregation platforms, new power electronics and more local engagement in balancing distributed generation to enable energy resilience."[51]

The amount of flexible demand in the GB system has actually reduced since 2013

2.64 However, many practical barriers to participation for providers of demand flexibility remain meaning its potential is not being realised. In fact, the amount of flexible demand in the system has actually reduced since 2013.[52] The following paragraphs set out the most important and well-understood barriers to participation.

Ancillary services provision

2.65 As explained in the discussion of storage technologies, many of the products that National Grid has historically procured to keep the system stable (ancillary services) were designed around what generators could offer. This has led to unintentional features in the design and specification of these products, which prevents demand flexibility from providing them. Barriers identified in our call for evidence include:

- large minimum bids
- requirements for fixed quantities of flexibility to be available for long periods

- activations that are too frequent or have unnecessarily long maximum durations
- requirements for symmetric bids
- quantities fixed a long way ahead of real time
- prohibitively expensive telemetry requirements

2.66 In recognition of this, new products such as "demand turn-up" are being trialled to provide National Grid with more demand side options to call upon. However, rather than create more products in an already complex setup, a more fundamental redesign of the products that National Grid procures may be a better long term option.

"over the longer term there will be a need for National Grid to look at its suite of balancing services in the round and ensure they are simple, customer-led, and focussed on securing least cost services, whether from generation, demand response or storage."[53]

The role of aggregators in the balancing market

2.67 Aggregators are unable to access the UK's electricity markets on equal terms with generators. In the balancing market, there is no defined role for third parties, which makes it difficult for them to participate. Energy UK's response to the Commission's Call for Evidence set out the consequences of this.

"Most demand side response does not currently have access to the Balancing Market. When a customer reduces demand at a time of system stress, it is their supplier that benefits, so only that supplier is motivated to buy this flexibility from the customer. This precludes the involvement of independent aggregators, who are responsible for the majority of demand side participation in the capacity market and in ancillary services."[54]

2.68 To address this, we recommend Ofgem reviews the Balancing and Settlement Code to ensure market arrangements for aggregators promote efficiency and the interests of consumers. This should allow for more demand side solutions to come forward.

Demand flexibility in the capacity market

2.69 Another potential source of revenue for demand flexibility (and storage) is the capacity market. This was created to make sure the UK has enough reliable sources of electricity in the wholesale and balancing markets at periods of peak demand, as there would not otherwise be a strong commercial case for building generating capacity that is only used very sparingly. For this reason, all participants are given a steady payment, even when they are not generating power, in return for capacity being available when needed.[55]

"The capacity market has been established to fit conventional providers of support rather than considering all potential providers."[56]

2.70 Less than 1% of the capacity procured in the most recent capacity market auction was load-shifting demand response, which represents only £8 million of the £942 million that will be paid out in 2019.[57] Whilst a low number, this represents a doubling of the amount of demand flexibility successful in the first auction – this growth may continue, reflecting the experience in some other capacity markets where flexible demand participation has grown over time from initially low levels. It is highly likely, that demand flexibility could contribute at low cost to enabling peak demand to be met, even if the scale of its contribution would be driven by the market.

Less than 1% of the capacity procured in the most recent capacity market auction was load-shifting demand response

2.71 As the capacity market evolves, the clear goal must be ensure that demand flexibility participates fully in the main capacity market, with a move away from transitional arrangements; ensuring that capacity is procured on a level playing field. This particularly applies to demand shifting, not just demand flexibility delivered through back-up generators. The Commission also sees a case for sharper allocation of the costs of the capacity market to incentivise consumers to reduce demand at peak times. Given the recent creation of the market, we suggest that the right moment to pick up these issues is in the 2019 review of the need for a capacity market.

2.72 It is clearly difficult to determine what represents a level playing field for the diverse technologies that can participate in the capacity market, and the different characteristics they have. However, respondents to the Commission's Call for Evidence stated that some of the rules are unnecessarily complex and do not take into account how technologies which are not generation are operated.

"Issues include unnecessary complexity and cost in metering arrangements, requirements for excessively frequent tests, lack of flexibility in portfolio formation, and no provision for portfolio maintenance."[58]

2.73 DECC should consider whether any administration of this regime, such as the rules around testing and the makeup of portfolios of capacity, unintentionally precludes the participation of demand flexibility and storage and need to adapt without delay.

Encouraging industrial and commercial consumers to participate

2.74 Demand flexibility can provide real value to firms and households without impacting on how they run their businesses or live their lives. For larger consumers in the UK, many of the necessary enablers for them to provide flexibility are already in place.[v] The Commission believes that more companies can reap the benefits of consuming cheaper electricity at off-peak times, with no reduction in output or detriment to their operating models.

2.75 Although demand from the industrial and commercial sectors represents more than half of total demand at peak times, wider cultural barriers are at play which prevent the large scale use of demand flexibility to save money amongst these users.[59] Ofgem's own research concludes that 'many, including commercial customers, are prevented from participating more fully because they are unclear about the monetary benefits of providing flexibility, as well as of the programmes available to them'.[60]

2.76 In addition, for each company the decision to provide demand flexibility competes with other options and investments for management attention.

"Energy costs make up less than five per cent of overheads for three quarters of companies; something more than price is needed to bring energy to the attention of those business leaders."[61]

2.77 The Government's immediate focus should therefore be to encourage these consumers to make the most of this opportunity.

Demand flexibility at a domestic level

2.78 Once smart meters are installed in homes across the UK, households will be able to save money by moving their demand to off-peak times. In order for these consumers to directly engage with and benefit from demand flexibility, Ofgem needs to ensure that the regulatory framework incentivises suppliers to offer 'smart tariffs', so that the prices people pay can reflect the cost of providing electricity over time (eg on a half-hourly basis).

"For demand side management to occur on a larger-scale the connection between wholesale power prices and consumers' power prices needs to be made."[62]

[v] These enablers include: meters capable of recording and submitting half-hourly consumption data, 24 half hourly settlement with the associated supplier and central IT systems, and ToU network charges.

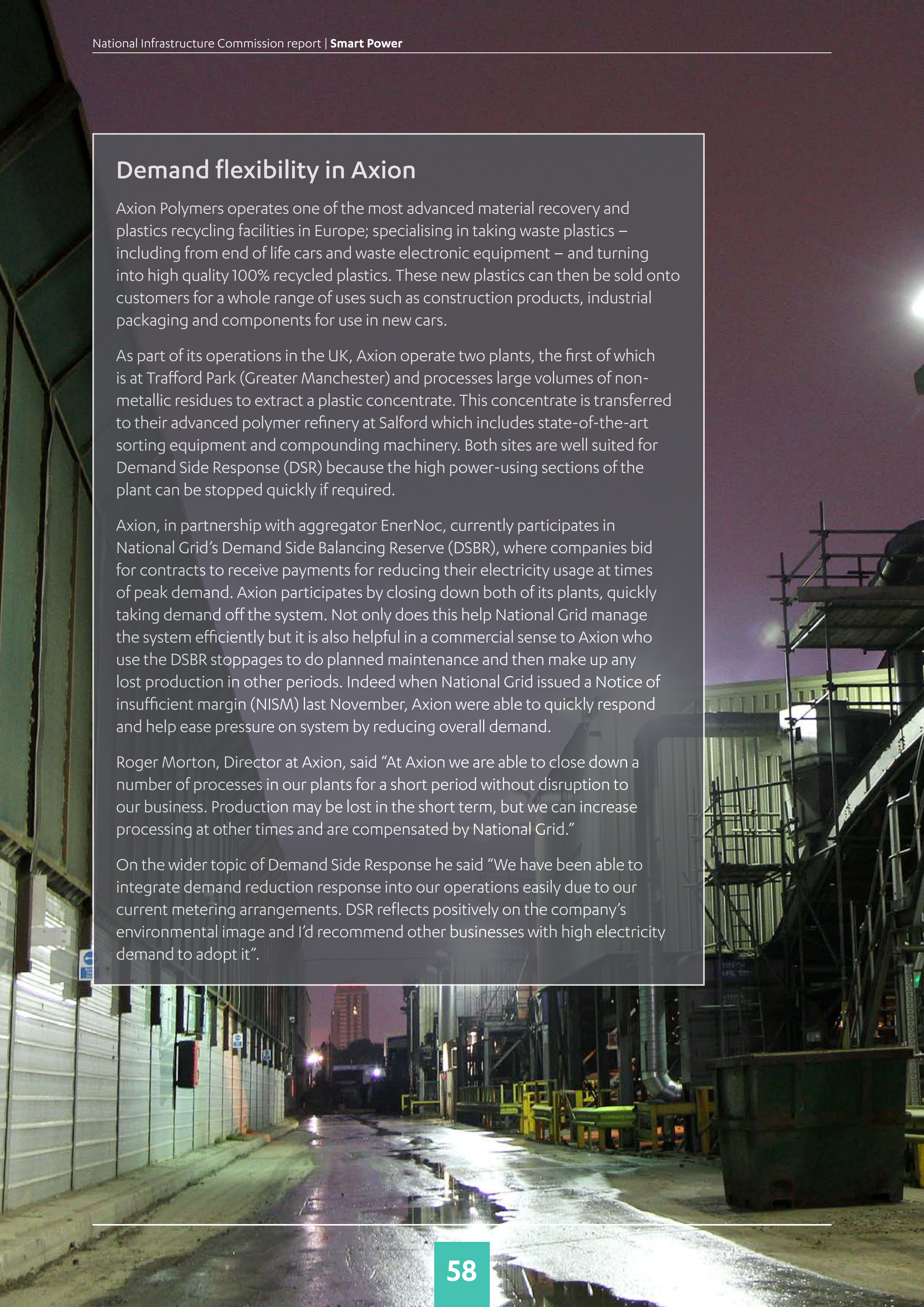
2.79 Once the necessary infrastructure is in place, domestic users will be able to manage their demand for electricity in response to price signals. They may either do this themselves or use automated systems, for example to ensure their appliances operate at the most cost-effective times of day. It is of utmost importance that consumers are supported in this transition, to make sure they understand how to benefit from these changes.

2.80 This will create a further set of opportunities for network operators, the scale of which would increase again as new technologies such as electric vehicles or domestic storage are rolled out.

"As demand response technology and energy storage become easier to implement and aggregate into the domestic market, large portfolio owners (such as Housing Associations) will be able to be offer demand aggregation at scale to the Grid, providing a new set of partners the National Grid can work with to shave peak demand."[63]

Learning and pilots

2.81 There is a significant role for pilots demonstrating how demand flexibility can work in practice in the UK. This is because the UK has a unique set of regulations and consumers, which limits what we can learn from other countries in terms of areas such as behaviour change.[64] The Government Estate offers an opportunity to pilot measures to manage demand flexibly and to implement them on a large scale where they can be shown to deliver significant benefits.



Demand flexibility in Axion

Axion Polymers operates one of the most advanced material recovery and plastics recycling facilities in Europe; specialising in taking waste plastics – including from end of life cars and waste electronic equipment – and turning into high quality 100% recycled plastics. These new plastics can then be sold onto customers for a whole range of uses such as construction products, industrial packaging and components for use in new cars.

As part of its operations in the UK, Axion operate two plants, the first of which is at Trafford Park (Greater Manchester) and processes large volumes of non-metallic residues to extract a plastic concentrate. This concentrate is transferred to their advanced polymer refinery at Salford which includes state-of-the-art sorting equipment and compounding machinery. Both sites are well suited for Demand Side Response (DSR) because the high power-using sections of the plant can be stopped quickly if required.

Axion, in partnership with aggregator EnerNoc, currently participates in National Grid's Demand Side Balancing Reserve (DSBR), where companies bid for contracts to receive payments for reducing their electricity usage at times of peak demand. Axion participates by closing down both of its plants, quickly taking demand off the system. Not only does this help National Grid manage the system efficiently but it is also helpful in a commercial sense to Axion who use the DSBR stoppages to do planned maintenance and then make up any lost production in other periods. Indeed when National Grid issued a Notice of insufficient margin (NISM) last November, Axion were able to quickly respond and help ease pressure on system by reducing overall demand.

Roger Morton, Director at Axion, said "At Axion we are able to close down a number of processes in our plants for a short period without disruption to our business. Production may be lost in the short term, but we can increase processing at other times and are compensated by National Grid."

On the wider topic of Demand Side Response he said "We have been able to integrate demand reduction response into our operations easily due to our current metering arrangements. DSR reflects positively on the company's environmental image and I'd recommend other businesses with high electricity demand to adopt it".

2.82 There is also an opportunity here for UK firms. We are a world leader in the data analytics and software development that can be used to manage energy demand seamlessly: showing what can be achieved will enable these capabilities to be marketed to the world.

Recommendation 3: The UK should make full use of demand flexibility by improving regulation, informing the public of its benefits and piloting business models.

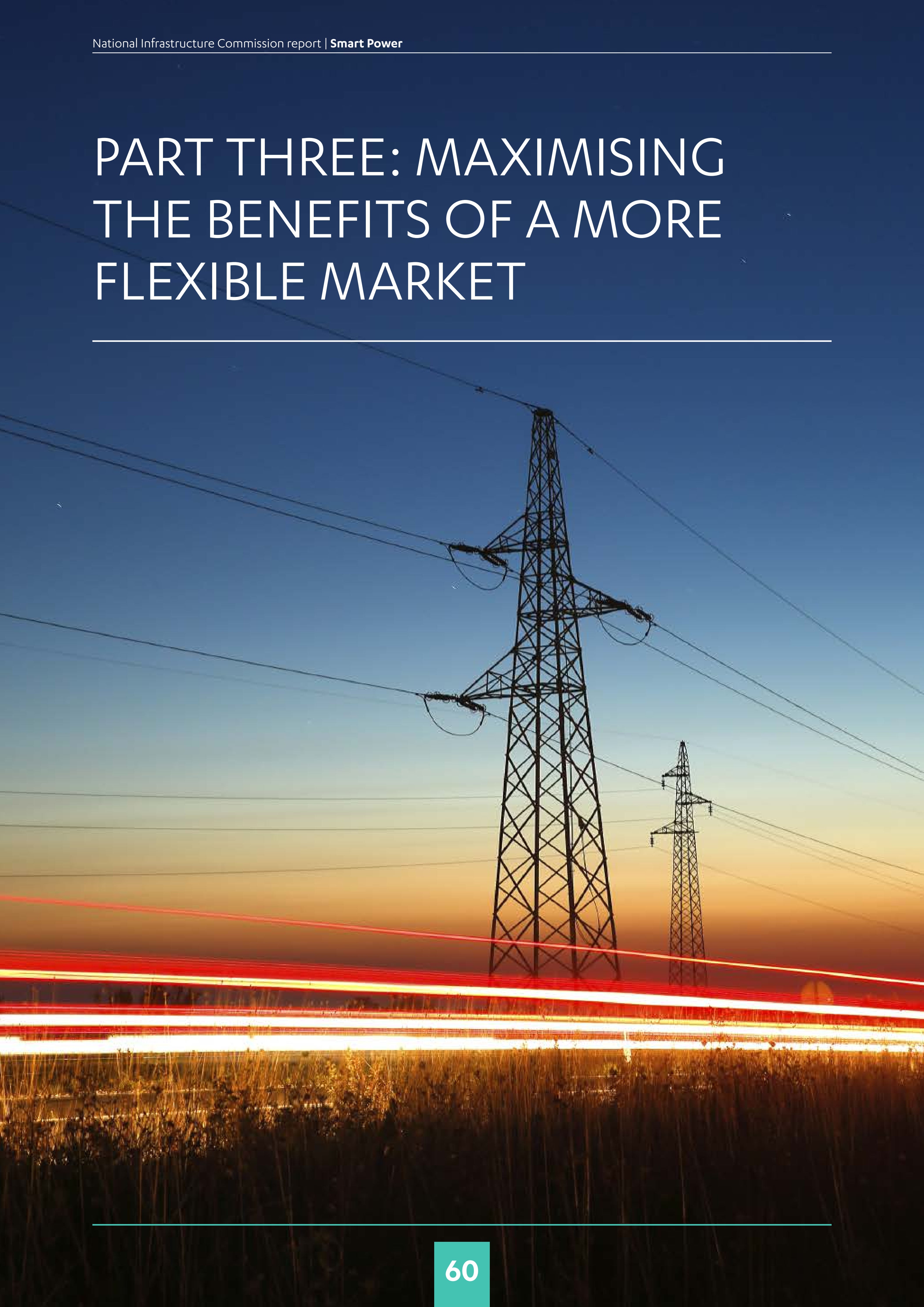
a) Ofgem should start an immediate review of the regulations and commercial arrangements surrounding demand flexibility with a focus on making participation easier and clarifying the role of aggregators; this should be complete by Spring 2017.

b) DECC should make future changes to the capacity market to reduce the costs and barriers to entry for demand flexibility.

c) DECC, Ofgem and National Grid ensure that large users and opinion formers are aware of the money saving opportunities that demand flexibility can offer and encourage more industrial and commercial consumers to take part.

d) Pilots focusing on business models which make demand flexibility easy and attractive to consumers should be established and fully evaluated. Government should demonstrate best practice by investigating the scope for demand flexibility on its estate.

PART THREE: MAXIMISING THE BENEFITS OF A MORE FLEXIBLE MARKET



3 MAXIMISING THE BENEFITS OF A MORE FLEXIBLE MARKET

3.1 The UK requires a national System Operator able to keep up with an increasingly complex system, more active management of our local networks, and a strategic approach to upgrading our networks.

A smarter system operator

Creating an Independent System Operator

3.2 The system operator plays a critical role in ensuring that Great Britain has secure electricity supplies and that demand can be met on a second by second basis. To date the UK's system operator has been very successful in delivering this. Going forwards, the system operator's place at the centre of the electricity system means that it will have a vital role to play in ensuring that the transition from large fossil fuel power stations to an increasing complex mix of smaller, more diverse, intermittent generation happens as smoothly as possible.

3.3 National Grid, a privately owned company, is the current system operator for the British electricity system. Alongside its system operator role, it owns the electricity transmission network in England and Wales and has interests in the development of interconnectors between Britain and other countries. Following the changes to the electricity market put in place by the Government's recent Electricity Market Reform (EMR) programme it also has a role in advising the government on security of supply and running the auctions for both the capacity market and the allocation of Contracts for Difference (CfD). A system operator that also owns parts of the transmission network can allow synergies in the running of the system, for example understanding where the most beneficial upgrades to the network can be made. Its in depth knowledge of the electricity system and its role in ensuring electricity supplies are balanced also makes it well placed to advise on longer term security of supply.

3.4 However, the fact that National Grid is a private company and has interests across the electricity market, mean that there is the potential for perceived conflicts of interest. For example, National Grid both runs the capacity market process and bids in to receive capacity market payments for the interconnectors it owns. The Commission has found no evidence that National Grid has acted in any way that has led to a conflict; however, as the functions the system operator needs to carry out are likely to increase as the electricity system evolves, the scope for perceived conflicts for interest may also increase.

"We consider National Grid to be a high quality and responsible company. It is doing a robust job in managing the grid nevertheless intermittent renewables are making balancing and managing the grid more challenging."[65]

3.5 Potential conflicts of interest within the system operator were set out by many of the respondents to the Commission's call for evidence.

"We consider that recent policy changes have created increasingly deep conflicts of interest around the role of National Grid as the System Operator."[66]

"While we do not see evidence that potential conflicts of interest is occurring in practice ... this perception could affect investor, political or consumer confidence in the UK market."[67]

3.6 On balance, there appears to be merit in increasing the independence of the system operator to guard against the risks of conflicts of interest and to help it to address the challenges the electricity system will face. However, it is not clear whether an entirely independent system operator (ISO) is the right model to adopt to solve these issues. Whilst a truly independent system operator, particularly if set up as a not-for-profit organisation, would not face actual or perceived conflicts of interest there are trade-offs, including the increased difficulty in setting its incentives.

3.7 Many of the benefits around mitigating conflicts of interest could be achieved through further separation of the system operator function within National Grid without a wholesale move to an ISO – a step from which there would be no going back.

3.8 Importantly, the challenges in correctly designing the framework within which an independent system operator would work and the changes needed to the wider electricity system to make this move are sizable. There is a risk that that a focus on this would distract from delivering other the important changes that are needed to the system, for example encouraging more active management of the local distribution network.

3.9 Given the case for greater system operator independence. DECC and Ofgem should continue to examine how they minimise any perceived conflicts of interest. However, it is the Commission's view that the move to an entirely independent system operator should not be a priority. Instead, the existing system operator should work to ensure that the electricity system is able to deliver the flexibility that is needed, for example through closer coordination with the local distribution networks and making changes to how they procure services to stabilise the system.

"there are more important elements of the policy infrastructure that need to be amended. In terms of creating the level playing field an ISO should be developed as a final stage."[68]

3.10 It is important for the system operator to be more independent, and National Grid should work to achieve this. The strength of the case for an entirely independent system operator is likely to change over time, depending on how the electricity system evolves. Government should therefore keep this area under review.

The future of system operation

3.11 As the system evolves, with more and smaller power stations that are less flexible, increased deployment of storage, greater interconnection, and increased usage of demand flexibility, operating the transmission network will become significantly more complex. The system operator should be encouraged to invest in the necessary digital infrastructure and capability to optimise the system.

3.12 As a starting point, the System Operator is working with the distribution networks to improve its visibility of what is connected at different levels of the system. Increasing information sharing and strengthening interactions between the transmission system operator and other network companies will mean the whole system can be controlled in a more coordinated way, which is a key enabler for significant cost savings. The move towards more active management of the distribution networks described later in this chapter will also help facilitate this process.

3.13 In addition, evidence from recent research projects shows that investing in more digital infrastructure can enable system operators to reduce the amount of redundant physical assets which are currently used to ensure security of supply. Smart corrective-control measures can be used to achieve the same result, which can lead to efficiency gains and lowered costs.[69] The System Operator should be incentivised to make these investments where they may be expected to support long term cost savings for consumers.

The increasing need for ancillary services

3.14 The market for ancillary services is set to grow, as the number and volume of services required by the System Operator to manage the transmission system increases, particularly with high levels of intermittent renewable generation. National Grid's System Operability Framework sets out predicted future system requirements under the various future energy scenarios.

3.15 As set out in Part 2, National Grid are running a campaign called Power Responsive to encourage more demand side participation and are reviewing and making changes to services. They are also starting to design new products, such as Enhanced Frequency Response, so that the system can benefit from the full range of technologies that are now at its disposal.

3.16 However, for many of the services they procure there is not a level playing field between generators and other service providers. For example, the grid code mandates transmission-connected generators to be available to provide certain services to the network, but allows them flexibility over what they charge. Those who are able to provide these services but are not mandated to do so – such as storage providers - can tender for them, but are then are locked into making themselves available under the terms that the System Operator specifies.

"The requirement for flexibility is growing. We strongly believe that this provides an opportunity to reset the market framework for ancillary services such that it treats all sources of flexibility; demand side response, storage or generation equally...the use of greater standardisation of the products and procuring this via regular open auctions, as some other markets have adopted, would provide fairer access for all" [70]

3.17 The Commission believes that more needs to be done to remove barriers which prevent all potential sources of flexibility competing to provide ancillary services on equal terms. This means that Ofgem and National Grid should consider:

- Providing greater visibility of the tendering pipeline, both to other network companies and potential bidders.
- Tendering for multiple services at the same time rather than on an ad hoc basis. Allowing people to bid at the same time for multiple services will mean businesses are more able to make tradeoffs between providing different services.
- Developing mechanisms to specify and value what the system fundamentally needs. There are some things which generators provide which they are currently not compensated for (e.g. inertia). In addition, the design of some services – while delivering value to the electricity system – have been set around what generators could historically offer. Specifying services in this way is a barrier to innovation, as it makes it difficult to compare different solutions to the same need (for example, enhanced frequency response and inertia).
- Using this to design a simplified set of products which all technologies can compete for on an equal basis and which enable the costs of different options to be readily and transparently compared. Grid code requirements may need revisiting and bilateral contracting should be brought to an end wherever possible.

3.18 Given the Commission's recommendation to clarify the role of aggregators in the balancing market, the interaction between ancillary services and the balancing market should also be reconsidered and clarified.

3.19 Alongside consideration of these changes, Ofgem and the System Operator should also be encouraged to look at international examples of ancillary services markets. Some countries (for example New Zealand) procure ancillary services dynamically through a half-hourly spot market. This allows the System Operator to only buy the services they need at any given point in time and service providers to choose whether to make themselves available or make money in other parts of the electricity markets. A market of this kind would also provide cost-reflective signals for emerging technologies, such as storage, making them easier to invest in.

New Zealand Ancillary Services – Transpower's 'Reserve Management Tool

Just like in the UK, New Zealand has to ensure the electricity system remains stable with supply and demand constantly balanced (in New Zealand this means keeping the grid frequency at 50 Hertz). Both countries procure ancillary services, aimed at securing the stability of the electricity system in the case of sudden imbalance event, such as a large power plant or the Hgoing offline. However, the way New Zealand procures its ancillary services is different.

Simply put, Reserve Management Tool (RMT) continually identifies the biggest risk to the system staying in balance for each 30 minute trading period (usually equivalent to the largest generator going offline) and then ensures an optimised amount of reserve products are in place should there be a sudden system change. These products are broadly either additional generation (such as a power station) which can be quickly brought online or interruptible load, where large power users (such as industry) have agreed to quickly turn off to reduce demand.

These products are then grouped into Fast Instantaneous Reserve (FIR) and Sustained Instantaneous Reserves (SIR):

FIR – on the instantaneous loss of generation, reserve in this category must respond within 6 seconds to arrest frequency fall but FIR is only required to last 60 seconds.

SIR – this needs to be able to respond within 1 minute and last for 15 minutes to replace the FIR and the lost generation. Generation is then redistributed to account to release the SIR within the 15 minutes and return of interruptible load then follows.

One key advantage of RMT that is often cited is that it enables the system operator to continually analyse what is needed to cover the biggest risk and to procure an optimum level of reserve for the forthcoming trading periods. Another positive aspect of the reserve management framework is that it uses a transparent and simplified procurement framework, where providers are able to bid in FIRs or SIRs right up until the gate closure – meaning the costs are more reflective of the system requirements at that time.

Recommendation 4: The System Operator must create new markets that will allow open competition for the services it procures and ensure it keeps pace with the network it oversees.

a) **The creation of an entirely independent System Operator should not be treated as an immediate priority but should be kept under review in light of progress towards strengthening National Grid's independence.**

b) **Ofgem should consider how it encourages the System Operator to develop new markets to provide ancillary services which allow new technologies to participate more easily. The long term goal must be for a more strategic and transparent approach to the procurement of ancillary services and more cost-reflective charging.**

More active management of our local networks

"...is it enough to have a Transmission System Operator, or do we also need to develop Distribution System Operators?"[71]

3.20 As set out in part two, storage and demand flexibility can be put to use for a variety of purposes at different levels of the system, including both local distribution networks and the national transmission network, enabling supply and demand to be more effectively balanced and avoiding or delaying costly upgrades.

3.21 While these benefits may be felt across the system, with the exception of a small number of larger scale storage facilities and large industrial consumers, the connection and deployment of these technologies will generally take place at the distribution network level.

3.22 This presents significant challenges for the management and operation of the distribution networks. Currently the owners of the fourteen British distribution networks are required to ensure that their networks operate safely, efficiently and have sufficient capacity to supply the peak demand required by their customers.

3.23 When electricity flowed almost entirely in one direction through the distribution networks – from the connection to the transmission network (which in turn was supplied by large power stations) to the consumer, this was largely unproblematic. More recently, however, the pattern of generation in the UK has become more distributed, meaning more sources of power, particularly small renewables such as solar power and onshore wind, are being connected at the distribution level. As a result electricity is increasingly flowing in both directions through distribution networks, making their management and operation more complex. These changes mean that there is significant potential to reduce costs and improve efficiency by deploying technologies such as storage and demand flexibility.

3.24 Increasingly, technologies connected to the distribution network will need to be called upon to help manage the transmission network. This will require greater coordination than at present. One example of how problems could occur in future is National Grid's Enhanced Frequency Response scheme, which was launched in September 2015.

3.25 National Grid invited bids for capacity which could be used within very short timescales to manage unexpected fluctuations in supply. The scheme attracted a large number of bids for new storage facilities which would need to be connected to the distribution network, resulting in some distribution network owners having to manage applications to connect more than 2000MW of storage.[72] In assessing these proposals, National Grid will seek to select the lowest cost bids from a transmission system operator perspective. However, whilst the location of the storage makes little difference to the benefits at the level of the transmission network, the implications for the distribution networks are much more complex. In a useful location, storage could potentially be put to use to help manage local constraints, delivering valuable benefits, but if located in the wrong place, it could place increased reinforcement costs on the distribution networks.[73] The distribution networks, however, have limited opportunity to influence National Grid and storage developers' decision making.

"Distribution Network Owners have very limited means to give the locational signals needed to encourage energy storage developers to design their systems to support them. The same issue exists with other technologies in the area of Demand Response."[74]

3.26 With the volume of connection requests for renewables, storage and new buildings, rising fast, distribution network owners have started to respond to this challenge. Through the Low Carbon Network Fund, set up and funded by Ofgem over the period 2009 – 2015, over sixty new trials and partnership projects were undertaken by network owners. Between them, they should enable around £900m of savings to consumers in the period to 2023 and have enabled much of the technical learning required to enable network owners to make use of new technologies and services.[75]

"Whilst frameworks are in place to provide sufficient technical governance to meet the above challenges, changes to the energy market to facilitate active management of the network at distribution level will deliver benefits to customers in terms of security of supply, improved efficiency and costs."[76]

3.27 A distribution network owner whose primary role is ensure there are enough assets to transport electricity to consumers no longer looks sufficient to get the best out of our increasingly complex distribution networks. This is why the need to create "distribution system operators" was one of the core themes running through the responses to our call for evidence. These bodies would be tasked with actively managing the activity on their networks, rather than simply ensuring there is adequate physical capacity for electricity to get to where it needs to go.

"Distribution Network Owners need to be empowered to be part of setting up a decentralised energy network... This is the issue most frequently cited as severely holding back the modernisation of the UK power system"[77]

What are the benefits of creating distribution system operators?

3.28 There are several possible ways local distribution networks could be more actively managed. For example, this could be through an increased role for the transmission system operator, network owners evolving into local system operators or the creation of new organisations to manage local networks independently. It is unclear which of these approaches (or any other) is the best solution. The Commission expects DECC and Ofgem to consider the relative benefits of different models as part of their work to enable the transition to more actively managed local networks. We have used the term "distribution system operator (DSO)" to represent all of these options.

3.29 An active distribution system operator could be given responsibility for balancing the system at a local level in real time. There are three key benefits which could stem from this arrangement.

- First, a DSO with a clear idea of what the local network needs at each moment in time will be able to purchase or procure these services to manage its system, creating revenue streams and market signals to suppliers. It is currently difficult to put together a commercial business case for local level storage and demand flexibility measures, as their benefits are diffused across different parts of the system. This change will also incentivise the development of new and innovative business models, and save money for consumers by reducing or deferring the need for costly physical enhancements to the grid.

"A distribution system operator would undertake the conventional role of a distribution network owner but would also make full use of smart techniques to create value for the wider electricity system"[78]

- Second, better visibility of the network, combined with more monitoring, control and smart technologies means that network operators will be able to adapt to more complex and unpredictable electricity flows. This means that more distributed and intermittent generation will be able to connect to the networks at a lower overall cost to the system.

"Increasing diversity of local generation and consumption patterns suggests local balancing could more efficiently optimise supply and demand within regions and could complement/run in parallel to national balancing."[79]

- Third, it will enable better coordination between the transmission and distribution networks. A set of DSOs could have a role in ensuring the effective management of the interface with the transmission network and a coordinated system-wide approach. They could work with the transmission system operator to ensure that the benefits of new technologies such as storage and demand flexibility are maximised across the system as a whole, helping to coordinate what deploys when to ensure no detriment to local services. DSOs could operate local balancing markets, linked to the national balancing markets run by the SO.

"...it is essential that the national and local electricity systems are aligned and coordinated. With more electricity being generated at the distribution level there is a risk of making the balancing of the national system more challenging. It will be important for the transmission system operator and distribution system operators, who manage these systems, to coordinate their work."[80]

3.30 Enabling businesses to provide services to both the national and local networks would mean that they could be rewarded across the entire electricity value chain, making it easier for them to create viable business cases.

"distributed energy resources should be able to sell their services where it is the most profitable for them (e.g. balancing, system services, valuation in the energy market, congestion management, contracts with DSOs or TSOs as an alternative to grid reinforcement, etc.)"[81]

The "Sunshine" Tariff

Managing local generation and balancing more actively has the potential to reduce pressures on networks at times of peak demand, and to enable more renewable electricity generation to be connected. A project taking place in Cornwall is looking to do just that by shifting demand to times when solar power is generating.

South West Renewable Energy Agency (Regen SW) is working with Western Power, Wadebridge Renewable Energy Network and Tempus Energy to trial a new 'Sunshine Tariff' in Wadebridge. The project's particular aim is to resolve network capacity issues in the local area which is currently prohibiting the further deployment of renewable technologies.

The 'Sunshine Tariff' incentivises customers to use electricity between 10am and 4pm in the summer months by offering cheaper prices during these times. If the trial is successful in demonstrating that demand can be reliably and consistently shifted to times when solar panels are generating, it could open the door for new renewables projects to connect to the network where previously it would have been considered at capacity.

3.31 In the longer term, as new technologies such as electric vehicles start to be deployed at scale, they will provide a new source of electricity storage, linked into the distribution system through domestic connections. Vehicles can be charged overnight and during periods of low demand, but often remain connected to the network at other times of the day as well. DSOs could ensure that as they connect to the network, they are able to play a role from the beginning in helping to support the system. The technology to do this already exists.

"The integration of energy balancing mechanisms with electric vehicles is a cornerstone of the future of the electric system."[82]

3.32 For all these reasons, the Commission believes that the establishment of distribution system operators should be treated as a priority by Ofgem and DECC. As set out above, some steps have already been taken in the right direction, such as the establishment of the Low Carbon Network Fund, but progress has been slow. DECC and Ofgem need to grasp this issue and ensure that progress is accelerated.

"It will be essential in the very near future that Distribution Network Operators transition to Distribution System Operators with a function for not just maintaining and managing the wires in their network, but also managing and balancing the energy flows."[83]

Recommendation 5: Enabling the transition to more actively managed local networks should be a government priority. By Spring 2017 DECC and Ofgem should consult and set out how and under what timeframe this transition should best take place.

3.33 As part of this transition process, DECC and Ofgem will need to determine whether the distribution system operator should be the same organisation as the distribution network owner. Whilst it is logical to see how network owners could continue the process of evolution to become system operators, this may not be the best end result.

3.34 DECC and Ofgem will also need to reach a view on whether DSOs and network owners should be allowed to own and operate storage on their networks, or whether they should only be allowed to procure it. It is the Commission's view that network owners should not be the owners of large storage assets, but regulations and the associated contractual arrangements need to allow network owners to buy services from storage assets where appropriate.

A strategic approach to upgrading our networks

3.35 Ofgem have recently started to incentivise greater innovation and new ways of delivering resilient electricity networks. The implementation of the new RIIO price control framework (Revenue=Incentives+ Innovation+ Outputs (RIIO)) is an excellent first step. This has introduced longer price control periods for network owners, a specific innovation stimulus and a different approach to the treatment of costs, which should encourage companies to pursue the optimal approach (whether capital investment or an alternative solution) to deliver the requirement outputs.

3.36 But as the potential for new technologies increases more must be done. Ofgem needs to ensure that network companies are making the most of opportunities to implement technological solutions which can save consumers money by delaying or reducing the need for expensive upgrades and grid reinforcements. As these tend to be less capital-intensive than traditional solutions, deploying them enables companies to react quickly to unfolding uncertainty whilst deferring the need for bigger long term investments. Ofgem needs to ensure that future planning frameworks enable and incentivise the adoption of these solutions where appropriate in order to fully capture the diverse benefits that smart technologies can bring.

3.37 In many instances, a more strategic approach to upgrading our networks could deliver large savings to future consumers, or bring wider economic and social benefits to a local community. When planning ahead for the future, it often makes sense to exploit economies of scale. Once reinforcement to a network is required, there can be significant benefits to oversizing the new capacity that is installed, either to cope with future demand or to manage losses efficiently.[84] The additional costs of a larger cable are small compared the other costs involved in upgrading a network, for example digging up a road; the cost savings from not having to do further reinforcement a number of years later can be large.

3.38 It is important that investment decisions take account of the long term benefits for consumers of oversizing as well as the immediate costs of upgrading to a higher specification. While oversizing parts of the network on the basis of uncertain forecasts of the future need clearly comes at the risk of stranded assets, and hence consumers paying for something that is unused,[vi] in many cases this risk will be outweighed by the potential long term cost benefits of building in flexibility at an early stage.

3.39 Ofgem has already developed specific frameworks for the transmission level to provide for strategic investment. There is also a need to consider the approach for distribution networks. This will require new approaches to managing and allocating risks and benefits. Network companies (and by extension consumers) may not always be well placed to manage these risks, or able to capture the full benefits, of oversizing for specific parts of the network. For example, in the case of connection requests for developments, such as new homes or offices, where there is uncertainty

[vi] This risk is particularly acute in relation to cables, as these tend to be designed for their location and not easily reused elsewhere, but even in this case the potential benefits will often justify oversizing.

over the long term level of capacity needed, the upside of oversizing to enable future growth is gained by the developer or the wider community, but the risks are not, which creates a disincentive to the network owner to follow this approach.

3.40 To address this issue, it may be appropriate for other parties, such as local authorities, to manage the risk of creating a stranded asset where oversizing is intended to support a wider development objective. Network companies should ensure they work closely with third parties, such as developers and local authorities, to help facilitate these type of arrangements.

Recommendation 6: Where upgrades to our networks are needed Ofgem should continue its work in encouraging network companies to make long term strategic decisions. Whilst this does increase the risk of stranded assets, the Commission believes that if there is a potential net gain to future consumers then this approach may be justified. If network owners are not best placed to manage this risk, they should work with third parties to help facilitate these investments.

GLOSSARY

GLOSSARY

Aggregators	Organisations offering services to aggregate energy demand or production from different sources to act as one entity in providing services to the grid
Ancillary services market	The ancillary services market is how the System Operator procures a number of products to help it manage the electricity system in case of unexpected shocks, such as the failure of a power system.
Balancing and Settlement Code	This is the governance arrangements for electricity balancing and settlement in Great Britain. It relates to how generators and suppliers act to ensure the electricity system remains balanced and the action for when imbalances take place.
Biomass	A renewable fuel of organic material, such as wood, plants or other waste. Biomass can be burned directly or processed into biofuels such as ethanol and methane
Cap and floor regime	The regulated mechanism to determine the returns for developers of interconnector projects once they are in operation.
Capacity	The maximum power available from the power sector or a power station at any point in time.
Capacity Market	In the capacity market (CM) the government determines what level of system security is required for four years ahead and then commissions National Grid (in its role as System Operator) to calculate the amount of capacity that would deliver this. National Grid then runs an auction to procure this capacity at the lowest price.
Carbon Price Support (CPS)	A carbon price support is a tax on fossil fuels used to generate electricity.
CO_2	Carbon dioxide.
Compressed Air Energy Storage (CAES)	Air is compressed and stored under pressure either in underground caverns or in above ground vessels. The air can then be expanded released to drive a turbine and generate electricity.
Consumers	People, organisations and businesses who consume energy.
Contract for Difference (CfD)	A subsidy mechanism to support low carbon energy deployment. The Contract for Difference sets a price per unit of electricity produced by the low carbon technology.

Day ahead market	Market for buying and selling electricity for delivery on the day after trading takes place. Part of the wholesale market.
DECC	Department of Energy and Climate Change.
Demand flexibility	Definitions of "demand flexibility" or "demand side response" vary. Some include purpose-built generation on the distribution network, as this can be used to manage demand on the transmission network. Other definitions restrict it to the use of assets that which were not originally built to help manage the system but can still play a role. This could include a backup generator built for a factory, but not a generator built for the primary purpose of supplying the grid. This report uses the latter definition. In all cases, the definition also includes tools and incentives to reduce or reschedule energy usage by consumers at times of peak demand.
Demand side response	See 'Demand flexibility'
Distribution network	The lower voltage, local, electricity network which is used to deliver electricity to most customers.
Distribution network owners	Privately owned companies who own the distribution network.
Distribution Network Use of System (DNUoS)	Charges to distribution network customers to recover the cost of installing and maintaining Great Britain's distribution system.
Electricity demand	The amount of electricity being demanded at a point in time.
Electricity generation	The amount of electricity being generated at a point in time.
Electricity grid	The collective name for the transmission and distribution networks.
Electricity Market Reform (EMR)	A set of government reforms to the electricity market introducing contracts for difference and the capacity market.
Electricity supply	The amount of electricity being supplied at a point in time.
Embedded generation	Power stations which are connected to the distribution network rather than the transmission network.
Enhanced Frequency Response (EFR) capacity	Technologies that can supply power to the network in less than a second – to better balance the electricity system.

Feed-in-Tariff (FiTs)	FiTs is a Government scheme which subsidises the deployment of small scale renewables.
Flexible generation	Generation which can provide faster stability services whilst operating at lower loads than current power stations, leaving more room on the system for lower carbon sources of electricity.
Flow batteries	Batteries where the energy is stored directly in the chemicals making up the electrolyte solution.
Flywheels	Energy is stored by rapidly spinning a rotor using an electric motor. The rotor can then be slowed, with the motor acting as a generator. Flywheels are starting to be deployed in grid applications, especially as they can respond to system needs very quickly.
Fossil fuels	Natural gas, coal and fuels from crude oil.
Generators	Generators own power stations, or other sources of power such as renewables, which they use to generate electricity.
Gigawatt (GW)	Unit of electrical power equal to 10^9 watts.
Independent System Operator	A model of the electricity market where the system operator is independent from any other organisation.
Interconnection	Interconnection is the physical linking of electricity transmission systems across borders to allow the cross-border trading of electricity.
Liquid Air Storage	Air is liquefied and stored in vessels, it can then be evaporated to drive a turbine and generate electricity.
Load-shifting	Shifting of electricity demand to another time in the day.
Megawatt (MW)	Unit used to measure capacity of power generator. 1 MW = 1,000 kilowatts.
National Grid	A British multinational electricity and gas utility company whose operations include owning transmission network assets, part of the national gas grid and acting as System Operator.
Ofgem	The regulator for gas and electricity markets.
Operating reserve	The generating capacity available to the System Operator within a short interval of time to meet demand in case other generation is not available, demand changes unexpectedly or there is another disruption to the supply.

Peak demand	Denotes the maximum power requirement of a system at a given time, or the amount of power required to supply customers at times when need is greatest.
Peak load	See 'Peak demand'
Power purchase agreements (PPAs)	A contract between a generator and a licensed electricity supplier for the sale of the output of the generator for the contract duration at a price that is defined in the contract.
Power station	A facility for the generation of electricity.
Pumped storage	Energy is stored by pumping water up to a reservoir to be released when needed, generating electricity through hydro-electric turbines.
Renewable electricity	Renewable electricity includes biomass, solar power, wind, wave, tidal, and hydroelectricity.
Retail market	Where consumers are able to choose their supplier of electricity from competing retailers.
Revenue=Incentives+ Innovation+ Outputs (RIIO)	Ofgem's framework for setting price controls for network companies.
Smart meters	Automated digital gas and electricity meters.
Smart technologies	Appliances and technology where the energy use can be automatically controlled – often remotely.
Storage	The ability to store electrical power for use at a later time.
Suppliers	Suppliers buy electricity from either the wholesale market or directly from generators and then sell this to firms and households (the retail market).
System Operator	The System Operator (SO) is responsible for ensuring the electricity system remains balanced within each half hour period. The SO ensures that imbalances in supply and demand are addressed on a second by second basis, within the constraints of the network. National Grid is the System Operator for the GB electricity system.
The balancing market	The balancing market operates from 'Gate Closure,' one hour ahead of the agreed delivery time of the electricity, through to real time. It exists to ensure that supply and demand can be continuously matched or balanced in real time.

Transmission Network Use of System (TNUoS)	Charges to transmission network customers to recover the cost of installing and maintaining Great Britain's transmission system.
Transmission Network	The high voltage electricity network, used to move electricity long distances across the country.
Transmission Network Owners	Transmission network owners own the high voltage electricity transmission network.
TWh	An energy measure (usually electricity) equivalent to 1,000,000 MWh or 1,000 GWh. One GWh of electricity would meet the hourly energy needs of over 600,000 UK households.
Wholesale market	Great Britain has a liberalised electricity wholesale market where prices are not set by a regulator. The wholesale market is made up of bilateral contracts and trading over exchanges.

THE NATIONAL INFRASTRUCTURE COMMISSION

Chair

Lord Andrew Adonis

Lord Andrew Adonis was appointed as chairman of the National Infrastructure Commission on 5 October 2015. He was a member of the independent Armitt Commission, which recommended an independent National Infrastructure Commission in 2013.

Andrew Adonis was formerly the Transport Secretary from 2009 to 2010, Minister of State for Transport from 2008 to 2009 and Minister for Schools from 2005 to 2008. He was Head of the No10 Policy Unit from 2001 to 2005.

Commissioners

Sir John Armitt

Sir John Armitt is Chairman of the National Express Group and City & Guilds, Deputy Chairman of the Berkeley Group and a member of the Board of Transport for London, Senior Vice President of the Institution of Civil Engineers and a Fellow of the Royal Academy of Engineering, the Institution of Civil Engineers and City & Guilds of London Institute. He has received honorary doctorates from the universities of Portsmouth, Birmingham, Reading and Warwick and was awarded the CBE in 1996 for his contribution to the rail industry and a knighthood in 2012 for services to engineering and construction.

In September 2013 the Armitt Review, his independent review of long term infrastructure planning in the UK, was published. The review is now Labour Party policy.

Tim Besley

Tim Besley is School Professor of Economics and Political Science and W. Arthur Lewis Professor of Development Economics at the LSE. He was a co-chair of the LSE growth commission and a member of the IFS's Mirrlees Review panel, and is currently Chair of the Council of Management of the National Institute of Economic and Social Research.

Demis Hassabis

Demis Hassabis was the co-founder and CEO of DeepMind, a neuroscience-inspired AI company, bought by Google in Jan 2014. He is now Vice President of Engineering at Google DeepMind and leads Google's general AI efforts.

The Rt Hon Lord Michael Heseltine CH

The Rt Hon the Lord Heseltine CH was a Member of Parliament from 1966 to 2001. He was a Cabinet Minister in various departments from 1979 to 1986 and 1990 to 1997 and Deputy Prime Minister from 1995 to 1997. He is founder and Chairman of the Haymarket Group, and most recently was appointed by the government as an advisor to the Secretary of State for Communities and Local Growth.

Sadie Morgan

Sadie Morgan BA (HONS), MA (RCA), FRSA is a co-founding director at the award-winning practice, dRMM Architects. She became the youngest and only third ever-female President of the Architectural Association in 2013. In March 2015, Sadie was appointed as Design Chair for High Speed Two (HS2) reporting directly to the Secretary of State.

Bridget Rosewell

Bridget Rosewell OBE, MA, MPhil, FICE is a UK economist, with a track record in advising public and private sector clients on key strategic issues. She is a founder and Senior Adviser of Volterra Partner and a non-executive director of Network Rail and of Ulster Bank. She was Chief Economic Adviser to the Greater London Authority from 2002 to 2012. She has been a member of several Commissions looking at the future of public services, cities, infrastructure and local finance.

Sir Paul Ruddock

Sir Paul Ruddock is Chair of Oxford University Endowment Management and Chair of the Oxford University Investment Committee. Sir Paul was a co-founder of Lansdowne Partners in 1998 and CEO of Lansdowne Partners Limited from 1998 to 2013 when he retired. From May 2007 to October 2015 he was Chair the Board of Trustees of the Victoria & Albert Museum as well as Chairman of the Gilbert Trust for the Arts. He is a Trustee of the Metropolitan Museum of Art, New York and a Fellow of the Society of Antiquaries.

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