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The Resilience of the Electricity System

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CONTENTS

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Q in footnotes refers to a question in oral evidence.

SUMMARY

Modern society is vitally dependent on a reliable supply of electricity and a sustained failure in the electricity system would have dramatic consequences. It would result in a catastrophic failure of communications and of many services on which we are now heavily dependent. It would have an impact on the country's economy and on public safety to a much greater extent than even a decade ago.

The capacity margin, the surplus of electricity generating capacity over demand, was reduced this winter. This provoked speculation in the media that the country might be subject to national blackouts. It was against this background that we chose to investigate the resilience of the electricity system.

There has been no national blackout so far this winter, and we are not surprised. Nor do we expect the lights to go out next winter. It would take an improbable concatenation of events to put the lights out nationally. National Grid has tools at its disposal to increase capacity or reduce demand, and we are confident that it has the ability to maintain national electricity supply. As Professor Newbery and Professor Grubb put it to us: "there is no 'cliff edge' at which the lights go out, but rather an increasing array of options for managing tight conditions."[1] Indeed, National Grid procured extra capacity to raise the capacity margin from 4.1% to 6.1% this winter and guard against a potential shortage of electricity.

It is a matter for concern, however, that this extra capacity was put in place at short notice, at considerable cost, and in a way which conflicts with the decarbonisation agenda. This should not be allowed to happen again; it is not acceptable for an advanced economy, hugely dependent on electricity, to sail so close to the wind. Moreover, demand for electricity has declined substantially since the economic crisis began. If demand had continued to grow, capacity margins would have been much tighter.

The electricity market is now a managed market. The pursuit of decarbonisation makes a free market in electricity supply impossible while low-carbon sources of power are more costly than high-carbon ones. There must be clarity about roles and responsibilities across a sector which has many participants.

We do not think that the Government has sufficiently informed the public that, with the present and foreseeable state of technology, it is not possible for the electricity supply to be low-cost, resilient and low-carbon all at the same time (the so-called energy trilemma). If the Government pursues decarbonisation as an objective, in line with its legal and international obligations, and at the same time seeks to ensure that power remains reliably available at all times, this is likely to mean higher electricity prices, with attendant economic and social costs, at least in the short term.

We argue that it is imperative that the electricity system is viewed as a whole. It is important that an end to end approach is taken, so that complex interactions are not missed between the many component parts of the system. Adopting such an approach will be increasingly important as profound changes occur to the system. New technology is presenting huge opportunities, but also novel challenges to resilience. The projected increase in electrification of transport and heating, for

1 Written evidence from Professor David Newbery and Professor Michael Grubb (REI0026)

instance, will increase demand and has the potential to threaten resilience. In addition, current renewables, such as wind and solar, provide an intermittent supply of electricity which will need to be balanced. The uncertainties are manifold. The Government must maintain a flexible approach and nurture a range of technologies, including electricity storage, interconnection and Demand Side Response (DSR).

The Resilience of the Electricity System

CHAPTER 1: INTRODUCTION

Our inquiry

1. This report examines the resilience of the electricity system in Great Britain. It was inspired, in part, by widespread discussion about whether electricity supply would meet demand over this winter and next. We also looked at how resilience could be affected as the electricity system embarks on a period of profound change in the coming decades. This change is driven by technological development and the commitment to decarbonise electricity generation.

2. One factor which influences the resilience of the electricity system is the amount of electricity generation capacity available relative to the amount of electricity needed by consumers. This margin between supply and demand will be affected in the coming years as old power stations close. These closures result, for example, from power stations reaching the end of their natural lifespan or being unable to meet more stringent environmental standards. Around a fifth of the generation capacity which was available in 2011 is expected to close by 2020.[2] The Government estimates that £110 billion of investment in new power stations and grid infrastructure is needed to replace this lost capacity.[3]

3. Consumer demand for electricity is not constant throughout the day or throughout the year. In the UK, the demand for electricity is at its highest on winter evenings. The system is at its most vulnerable to unexpected events, such as power station outages, at this time. To ensure resilience, an appropriate margin between supply and demand is needed. This is known as the capacity margin and is the proportion by which the available electricity exceeds demand. It acts as "an insurance against occasional unexpected losses of power or surges in demand."[4]

4. Closure of old power stations, combined with insufficient investment in new electricity generation capacity, has resulted in the capacity margin being squeezed. In June 2014 a capacity margin of 6.7% was forecast for winter 2014/15, which was expected to fall further to 3% the following winter.[5] By October 2014, following a series of power station outages, National Grid reported that the capacity margin for winter 2014/15 would fall to 4.1%.[6]

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2 DECC, *Energy Security Strategy* (November 2012): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65643/7101-energy-security-strategy.pdf [accessed February 2015]

3 *Ibid.*

4 Royal Academy of Engineering, *GB Electricity Capacity Margin* (October 2013): http://www.raeng.org.uk/publications/reports/gb-electricity-capacity-margin [accessed February 2015]

5 Ofgem, *Electricity Capacity Assessment Report 2014* (June 2014): https://www.ofgem.gov.uk/ofgem-publications/88523/electricitycapacityassessment2014-fullreportfinalforpublication.pdf [accessed February 2015]; National Grid, *Winter Outlook 2014/15* (October 2014): http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=36714 [accessed February 2015]

6 National Grid, *Winter Outlook 2014/15* (October 2014): http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=36714 [accessed February 2015]

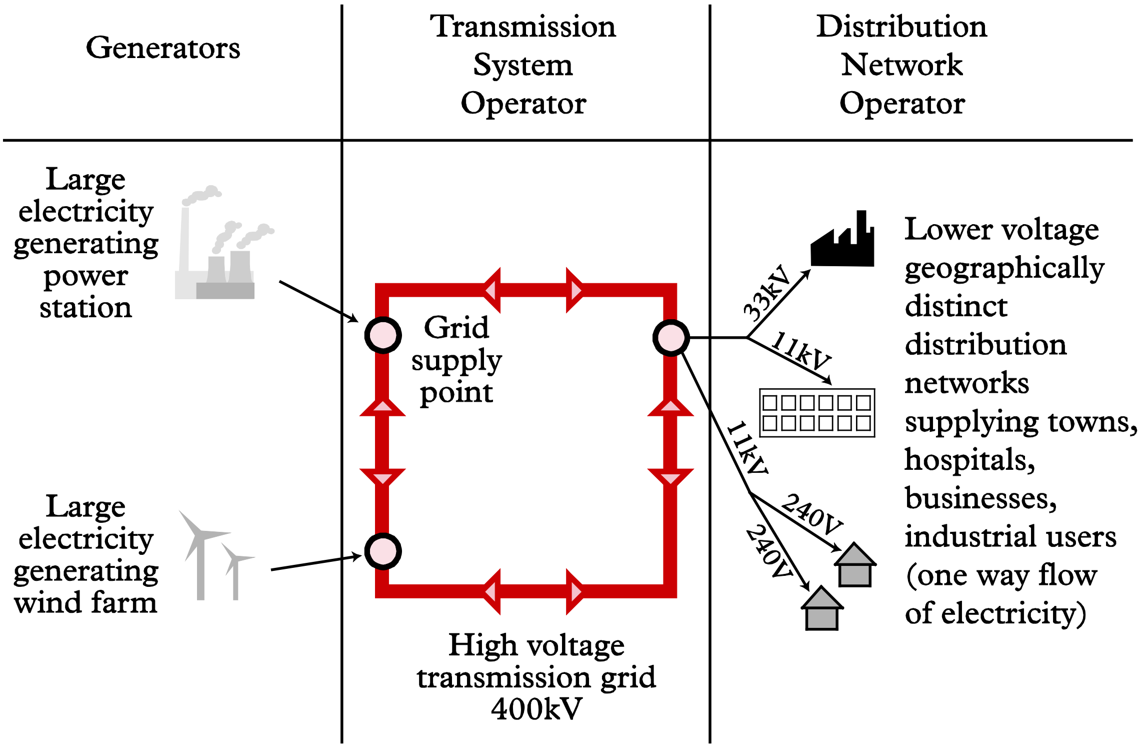
National Grid advised that it was putting in place short term measures to increase the available capacity. As a result of these measures the capacity margin has been increased to 6.1%. The narrowing capacity margin could present a risk to resilience of the electricity system. We therefore began our inquiry by investigating the implications of this and our findings are reported in Chapter 3 of this report. Further information about the capacity margin is provided in Box 2 in Chapter 3.

5. Generation capacity is not, however, the only factor affecting electricity system resilience. The resilience of the networks used to transport electricity around the country is of equal importance and it is vital that there is adequate investment to maintain and improve them. Resilience is also affected by consumer demand. An increase in demand, particularly at peak times, would also result in decreased capacity margins. Patterns of electricity demand could also change significantly in future, for example due to the widespread adoption of electric vehicles. Resilience is key to ensuring security of electricity supply, but is also central to affordability and sustainability. The following section of this chapter describes the components of the electricity system and identifies the different organisations with responsibility for its operation and resilience.

The Electricity System

6. As shown in Figure 1, the electricity system has four main components: generation, transmission and distribution networks and consumer demand. In this simplified diagram, electricity is generated at power stations or from renewable sources, such as wind farms, which are often distant from the centres of population where the electricity is needed. The transmission network (the ‘grid’) is therefore used to transport electricity over long distances. The grid operates at high voltages, which helps to minimise losses. Finally, the distribution networks transport electricity, at lower voltages, from the grid to the consumer. Whilst this diagram represents a ‘traditional’ view of the electricity system, as we will see in the following chapters of this report, today’s system is becoming increasingly complex. For example, rather than relying solely on large scale electricity generators, microgeneration from solar panels and wind turbines is becoming increasingly prevalent.

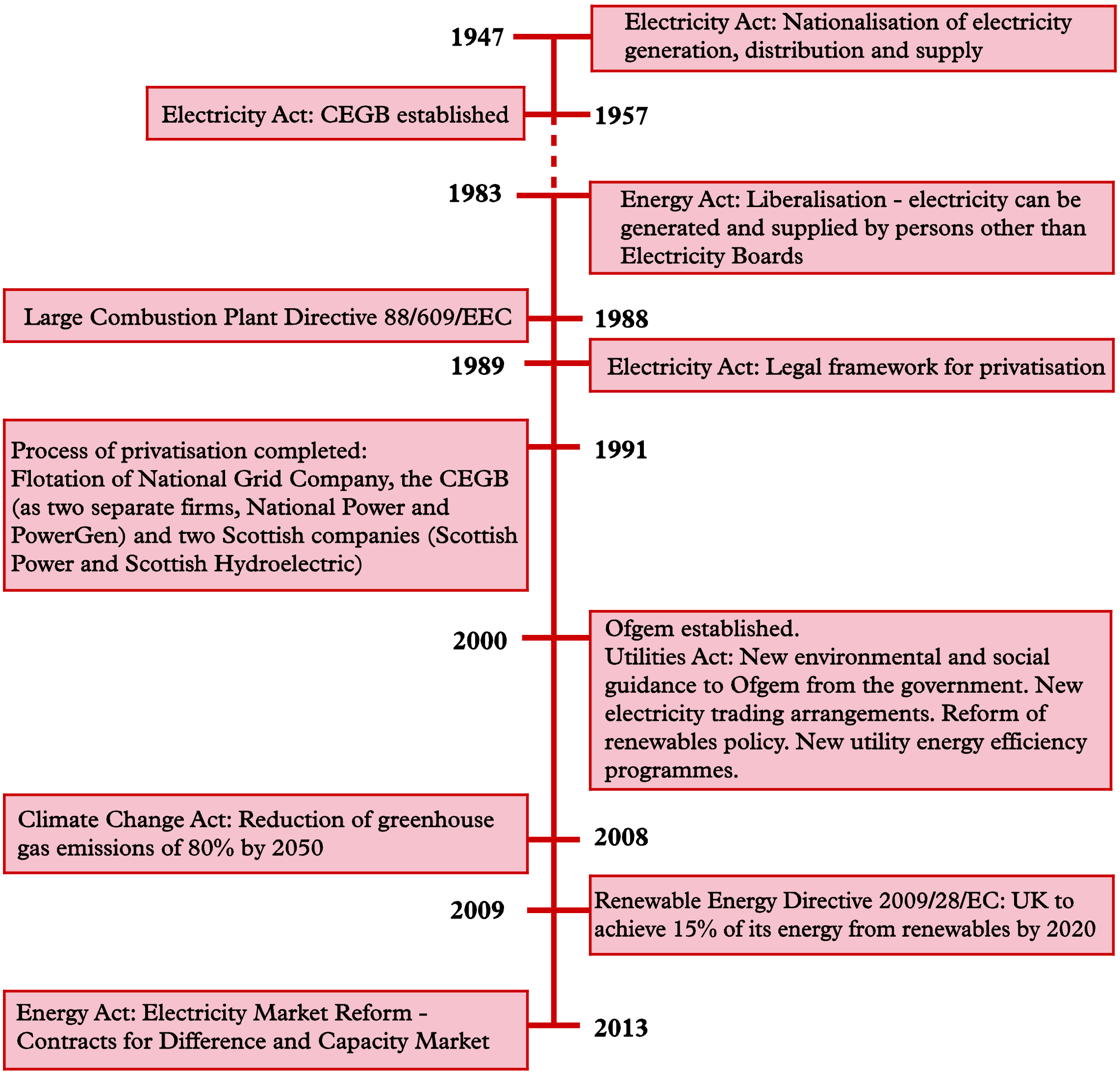
Figure 1: The Electricity System



Source: Adapted from the National Audit Office, Briefing for the House of Commons Energy and Climate Change Select Committee. The Electricity Generating Landscape in Great Britain. *(July 2010).*

7. The British electricity system was privatised in the 1990s with the aim of encouraging competition and keeping prices down. Prior to this, the Government had controlled all aspects of the electricity system through the Central Electricity Generating Board (CEGB). Further information about the history of the electricity system is provided in Figure 2. As described below, many different organisations are now involved. The electricity systems in Great Britain and Northern Ireland are governed and regulated independently of one another. This report focuses on Great Britain, although in some cases we make use of data which is reported at the level of the whole of the UK.

Figure 2: The History of the Electricity System



Source: adapted from IET, UK Energy Policy 1980–2010(2010) http://www.theiet.org/factfiles/energy/uk-energy-policy-page.cfm [accessed February 2015]

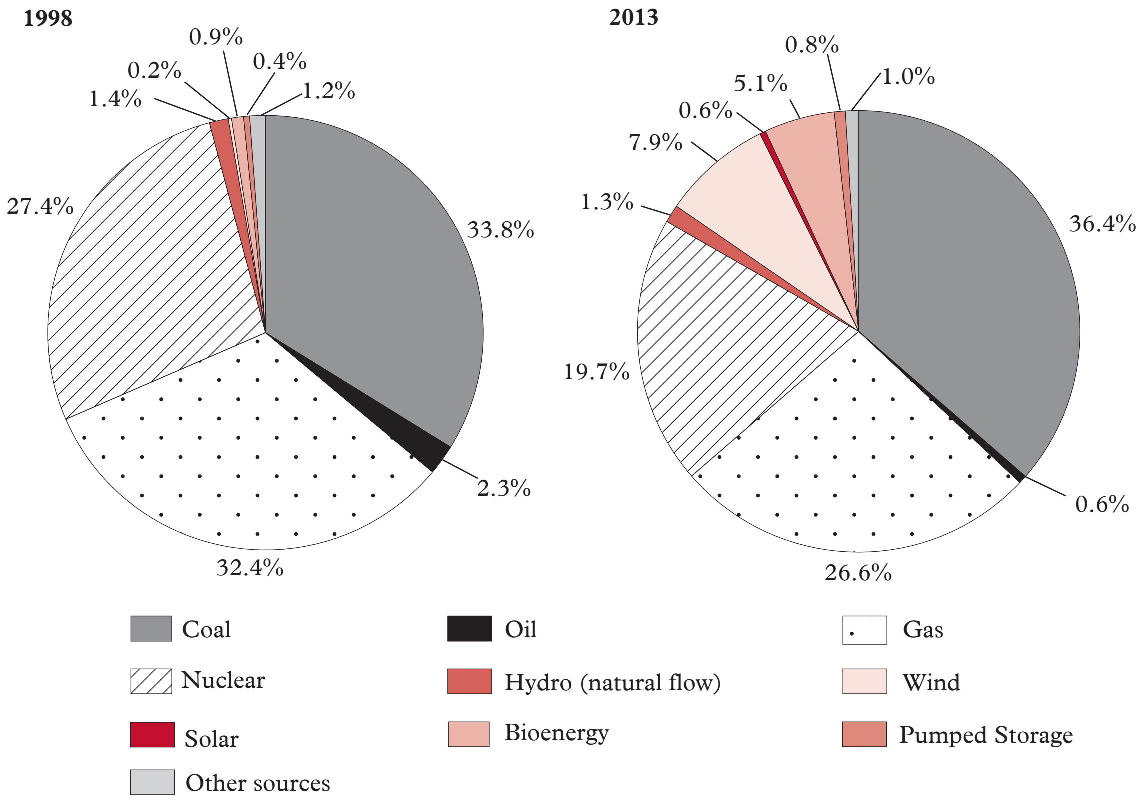
8. 359 TWh[7] of electricity was generated in the UK in 2013.[8] Electricity is generated by a range of different providers. Over 70% of generation capacity in Great Britain is, however, owned by just six private companies, often referred to as the 'big six;' Centrica, EDF Energy, E.ON UK, RWE npower, Scottish Power, and Scottish and Southern Energy (SSE).[9] Figure 3 shows the percentage of the UK's electricity generated from different sources in 2013, with 63.6% from fossil fuels, 19.7% from nuclear and 15.7% from renewables. In 1998, 68.5% of electricity was generated from fossil fuels, 27.4% from nuclear and 3% from renewables.

7 For further information, see Box 3 in Chapter 3.

8 DECC, *Digest of United Kingdom Energy Statistics 2014* (July 2014): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/338750/DUKES_2014_printed.pdf [accessed February 2015].

9 Ofgem, *State of the Market Assessment* (March 2014): https://www.ofgem.gov.uk/ofgem-publications/86804/assessmentdocumentpublished.pdf [accessed February 2015]

Figure 3: Percentage of Total Electricity Generation, by Source



Percentage of Electricity Generated by all generating companies from different sources. In 1998 this was of a total of 364 TWh. In 2013 this was of a total of 359 TWh.

Source: DECC, 'Fuel Used in electricity generation and electricity supplied' (December 2014): https://www.gov.uk/government/statistics/electricity-section-5-energy-trends [accessed February 2015]

9. The high voltage, long distance transmission network in Great Britain is operated by National Grid in its role as National Electricity Transmission System Operator (NETSO).[10] National Grid plc is an international electricity and gas company based in the UK and north eastern USA.[11] National Grid is responsible for coordinating and directing power flows across the transmission system in accordance with strict security standards set by the regulator, the Office of Gas and Electricity Markets (Ofgem). As electricity cannot be stored easily it is necessary to match supply and demand minute-by-minute. National Grid also owns the transmission network in England and Wales, whereas in Scotland it is owned by Scottish Power Transmission Ltd and Scottish Hydro Electric Transmission plc.[12]

10. Distribution networks are lower voltage, local networks which transport electricity from the grid to consumers throughout the country. There are 14 geographically distinct distribution networks owned by six different groups: the Distribution Network Operators (DNOs).[13] The DNOs are responsible for

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10 Written evidence from National Grid (REI0017)

11 National Grid, 'Our Company': http://www2.nationalgrid.com/UK/Our-company [accessed February 2015]

12 Written evidence from the Government (REI0040)

13 Ofgem, 'The GB electricity distribution network': https://www.ofgem.gov.uk/electricity/distribution-networks/gb-electricity-distribution-network [accessed February 2015]

the operation and maintenance of the distribution network in accordance with standards set by Ofgem.

11. Electricity is sold to customers, by suppliers, in the retail market. The 'big six' have a 95% share of the domestic supply market. The remaining 5% is made up from a number of smaller energy suppliers. Smaller suppliers, which do not have their own facilities for large scale electricity generation, buy electricity in the wholesale market.[14]

12. Ofgem is a non-ministerial government department with responsibility for regulating the electricity system. Ofgem fulfils these functions in line with policies set by the Department of Energy and Climate Change (DECC). DECC defines policy objectives, devises the legislative framework and sets security standards.[15]

Resilience

13. In this report we use the definition of resilience adopted by the Cabinet Office in their 2011 *Natural Hazards and Infrastructure*[16] report: "Resilience is the ability of assets, networks and systems to anticipate, absorb, adapt to and / or rapidly recover from a disruptive event." The report identifies four components to infrastructure resilience: resistance (level of protection), reliability, redundancy (spare capacity), and response and recovery. In this report, we examine all four aspects of resilience of the electricity system.

14. It is clearly important that the complex electricity system described above is resilient. Maintaining a constant supply of electricity, which is sufficient to meet demand, becomes ever more important as society becomes increasingly dependent on electricity.

15. As described in Chapter 4, there are many possible threats to resilience, such as extreme weather or cyber-attack. Resilience is affected if a system is vulnerable (or exposed) to a threat (or hazard). The key to ensuring that an identified threat does not result in a high level of risk is to ensure that vulnerability is controlled. As described in the Cabinet Office report: "Risk management is a process of identifying, understanding, managing, controlling, monitoring and communicating risk. This ensures investments are considered across the range of options and choices, and are proportionate to the risks. Effective risk management is the key to facilitating and building resilience."[17] It is important to note, however, that not all risks can be identified in advance and that part of the rationale for resilience is to try to ensure that systems, like electricity, will not be compromised if such risks have unforeseen impacts.

Government Policy

16. As described in Box 1, overall Government energy policy is influenced by the three competing demands of security, affordability and sustainability. Resilience is often understood as a component of security. It also, however,

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14 Ofgem, *State of the Market Assessment* (March 2014) https://www.ofgem.gov.uk/ofgem-publications/86804/assessmentdocumentpublished.pdf [accessed February 2015].

15 Written evidence from Ofgem (REI0044)

16 Cabinet Office, *Keeping the Country Running: Natural Hazards and Infrastructure* (October 2011): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/61342/natural-hazards-infrastructure.pdf [accessed February 2015]

17 *Ibid.*

has close interactions with the other two demands. Prices can affect the resilience of individual consumers by affecting their ability to pay for the energy services they need. The impact of energy systems on sustainability can, in turn, affect resilience (e.g. if future climate change leads to more extreme weather events).

17. The purpose of our report was to look specifically at the effects of Government policies on the resilience of the electricity system and to identify the measures which need to be in place to ensure future resilience. Although during the course of this inquiry we touched upon many policy areas, the aim was not to conduct a wholesale review of energy policy, but rather to look specifically at the effect of policies on electricity resilience.

Box 1: The Trilemma

The energy 'trilemma' is a term widely used in energy policy. It describes the difficulties associated with balancing three interconnected and competing demands. The Government has described it as: "The challenge of keeping the lights on, at an affordable price, while decarbonising our power system."[18] In this report we adopt the terminology used by National Grid: security of supply, sustainability and affordability.[19]

The trilemma acknowledges that there are costs associated with either increasing the security of energy supply or improving sustainability, which affects the ability of consumers to afford electricity. Equally, there can be trade-offs between improving sustainability and security of supply. There is much debate about whether the Government's policies result in an optimal balance between the three sides of the energy trilemma.

The need to decarbonise electricity generation is a key factor in the sustainability corner of the trilemma. The requirements for decarbonisation are set by the Climate Change Act 2008, which established legally binding targets for the reduction of greenhouse gas emissions by 80% by 2050.[20] The power sector accounts for around 27% of the UK's greenhouse gas emissions. The Committee on Climate Change[21] recommends early decarbonisation of the power sector as this provides opportunities for electrification and decarbonisation of other sectors such as heating and transport. The Committee on Climate Change therefore recommends that the carbon intensity of power generation should be reduced from 500 g CO_2/kWh to 50 g CO_2/kWh by 2030.[22]

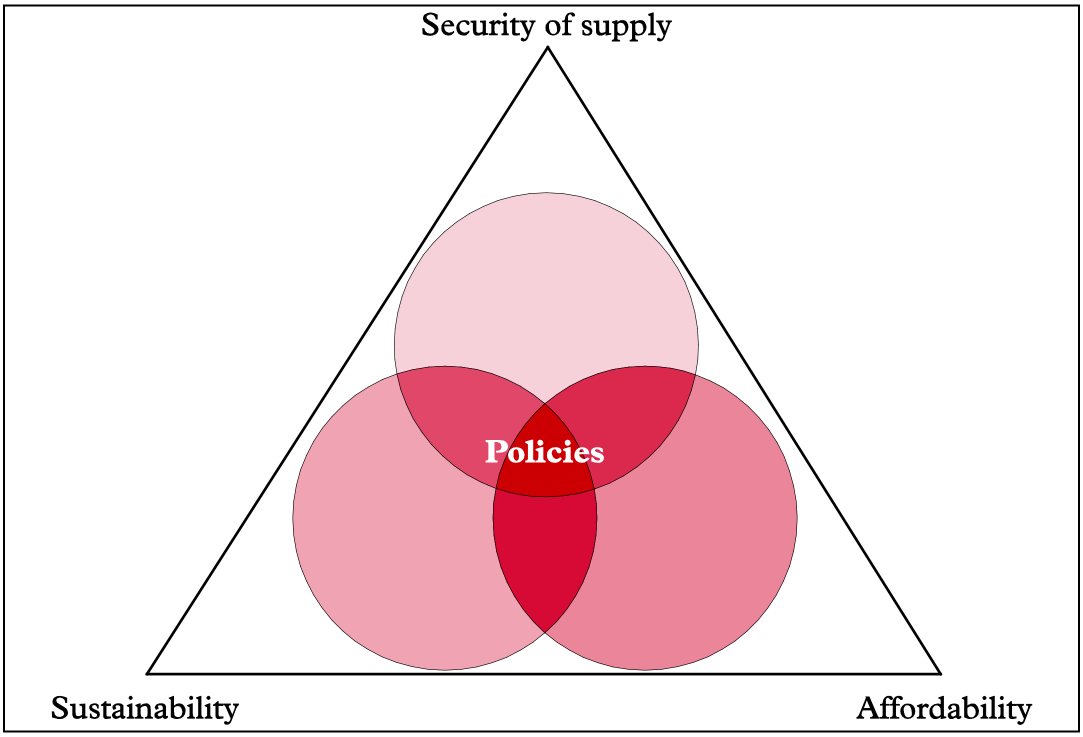
18 DECC, *Delivering UK Energy Investment* (July 2014): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/331071/DECC_Energy_Investment_Report.pdf [accessed February 2015]

19 National Grid, *UK Future Energy Scenarios* (July 2014): http://www2.nationalgrid.com/uk/industry-information/future-of-energy/future-energy-scenarios/ [accessed February 2015]

20 80% of 1990 levels.

21 The Committee on Climate Change (the CCC) is an independent, statutory body established under the Climate Change Act 2008. Its purpose is to advise the UK Government and Devolved Administrations on emissions targets and report to Parliament on progress made in reducing greenhouse gas emissions and preparing for climate change.

22 Committee on Climate Change, *Next steps on Electricity Market Reform* (May 2013): http://www.theccc.org.uk/wp-content/uploads/2013/05/1720_EMR_report_web.pdf [accessed February 2015]



18. Many different areas of energy policy relate to electricity resilience. Indeed, as the DEMAND Centre told us, areas of policy with seemingly no relevance to energy can have an effect on resilience due to their influence on energy demand.[23] The following paragraphs, however, briefly describe the main areas of Government policy which affect electricity resilience.

Electricity Market Reform

19. As part of the Energy Act 2013, the Government introduced Electricity Market Reform (EMR). The Government describes the aim of EMR as being to promote: "investment in secure and low carbon electricity generation, while improving affordability for consumers."[24] EMR introduced two important mechanisms which will affect the resilience of the electricity system; Contracts for Difference (CfD) and the Capacity Market (CM).

20. Contracts for Difference have been introduced to stimulate investment in low carbon electricity generation. CfDs aim to reduce the risk of investment: "by paying a variable top-up between the market price and a fixed price level, known as the 'strike price.'"[25] CfDs are not explicitly intended to improve resilience. This approach will, however, have an effect on the type of new generation capacity which is put in place to replace ageing power stations.

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23 Written evidence from the DEMAND Centre. "Energy policy does not influence end-use energy demand as much as other policy areas: land-use planning, transport, even health and education all influence the underlying dynamics of energy use." (REI0037)

24 Written evidence from the Government (REI0040)

25 DECC, *Investing in renewable technologies—CfD contract terms and strike prices* (December 2013): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/263937/Final_Document_-_Investing_in_renewable_technologies_-_CfD_contract_terms_and_strike_prices_UPDATED_6_DEC.pdf [accessed February 2015]

21. The Government intends that CfDs should apply to renewables, Carbon Capture and Storage (CCS) and nuclear.[26] The strike price has been set at different levels for different types of renewable generation, depending on factors such as the level of market maturity of the technology. For example, wave and tidal generation would receive a strike price payment of three times the value[27] of onshore wind or hydro power.[28] A 35 year CfD with a strike price of £89.50/MWh has been agreed for the planned Hinkley Point C nuclear power plant.[29] It remains unclear, however, how CfD allocation will work for CCS.

22. The Capacity Market, which is also referred to as the Capacity Mechanism, will be a key factor in improving short term resilience. As described by the Government:

> "The Capacity Market works by offering all capacity providers (new and existing power stations, electricity storage and capacity provided by voluntary demand reductions) a steady, predictable revenue stream on which they can base their future investments. In return for this revenue (capacity payments) they must deliver energy when needed to keep the lights on, or face penalties."[30]

23. This effectively provides an 'insurance policy' so that sufficient electricity can be made available to meet demand when the system is stretched. Capacity payments are won through a competitive auction held in two stages. The first stage procures capacity for four years ahead. A second stage is then held one year ahead to fine tune the amount of capacity available. The first capacity auction, which procured capacity for 2018, concluded on 18 December 2014. This auction procured 49 GW of additional capacity at a cost of nearly £1 billion.[31]

24. As the Capacity Market will not come into effect until 2018, interim measures have been needed to address the capacity shortfall. These measures, known as New Balancing Services (NBS) are explained further in Chapter 3 of this report.

Network Standards

25. A different mechanism is used to promote resilience of the transmission and distribution networks. These networks are owned and operated by national or

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26 DECC, *Delivering UK Energy Investment* (July 2014): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/331071/DECC_Energy_Investment_Report.pdf [accessed February 2015]

27 £305 per MWh for wave and tidal, £100 per MWh for hydro and £95 per MWh for onshore wind in 2014/15.

28 DECC, *Investing in renewable technologies—CfD contract terms and strike prices* (December 2013): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/263937/Final_Document_-_Investing_in_renewable_technologies_-_CfD_contract_terms_and_strike_prices_UPDATED_6_DEC.pdf [accessed February 2015]

29 DECC, 'State aid approval for Hinkley Point C nuclear power plant' (October 2014): https://www.gov.uk/government/news/state-aid-approval-for-hinkley-point-c-nuclear-power-plant [accessed February 2015]

30 DECC, 'Electricity Market Reform: Capacity Market design' (March 2014): https://www.gov.uk/government/news/electricity-market-reform-capacity-market-design [accessed February 2015]

31 National Grid, *Final Auction Results* (January 2015): https://www.emrdeliverybody.com/Shared%20Documents/Final%20Auction%20Results%20Report_v3.pdf [accessed February 2015]

regional monopoly companies. A regulatory approach is therefore used to ensure that the network operators perform to specified standards. Ofgem is responsible for these regulations, which they explained to us as follows:

> "In terms of resilience, in the short term they [the network companies] have a mixture of sticks and carrots regarding getting the number of interruptions and minutes lost down; if they outperform the targets we have set they can earn additional revenues, but if they fall short they lose revenue."[32]

26. Ofgem ensures that transmission and distribution network operators are making appropriate levels of investment in the networks using its RIIO price controls. RIIO stands for Revenue = Incentives + Innovation + Outputs. RIIO T1 applies to the Transmission Operator, National Grid. RIIO ED1 applies to the Distribution Network Operators.[33] The RIIO price controls were recently updated.[34]

27. In addition to the RIIO price controls, there are also commercial arrangements governing the networks. These arrangements are set out in the licence conditions of the network operators and in a series of industry codes. Finally, network companies are required to meet technical standards (defined by the Government) that outline the required level of resilience to disturbances.[35]

Audience

28. This report is made for the information of the House and the public. Insofar as we make recommendations for Government action, we address this report to the Government formed after the General Election.

Acknowledgments

29. We would like to thank everyone who gave evidence to us, both at oral evidence sessions, which were held between October 2014 and January 2015, and in writing. We are also indebted to our Specialist Adviser, Professor Jim Watson, whose knowledge and expertise greatly enhanced our work.

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32 Q 182 (Maxine Frerk)

33 Ofgem, *Price controls explained* (March 2013): https://www.ofgem.gov.uk/ofgem-publications/64003/pricecontrolexplainedmarch13web.pdf [accessed February 2015]

34 Written evidence from Ofgem (REI0044)

35 Written evidence from Ofgem (REI0044); Written evidence from UKERC (REI0031)

CHAPTER 2: THE ELECTRICITY SYSTEM

A managed market

30. As noted in Chapter 1, there are several participants involved in maintaining resilience: the Government, National Grid, Ofgem, the electricity generators and the Distribution Network Operators. The Secretary of State, Rt Hon Ed Davey MP, explained the interactions between these organisations.[36] He clarified that whilst all of these organisations have specific roles in maintaining resilience, ultimately, responsibility for resilience of the electricity system lay with him.

31. During our inquiry we heard concerns about the governance of the electricity system and how recent changes (see Chapter 1) had altered the relationship between the market and the state. We were told that the market led approach, by which successive governments have set great store, has been eroded and that decisions are being made centrally. GDF SUEZ Energy UK-Turkey asserted that:

> "The UK no longer has a fully market led approach … The UK is entering a period whereby a managed market will prevail with some aspects of a liberalised market being retained. Industry stakeholders will have to engage with this structure."[37]

32. Dr MacLean, Honorary Fellow of Energy Policy at the University of Exeter, argued that the Secretary of State had accrued significant powers to intervene. He asserted, however, that central planning had not spawned an explicit plan:

> "… we now have a situation where the Secretary of State probably has far more powers to intervene than he ever did in the days of the CEGB [Central Electricity Generating Board]. We are more in a central planning world than we ever were in the CEGB, except we do not now have an explicit plan. We do not have an explicit organisation that counterbalances the views of the Secretary of State. I think the Committee should also ask whether we have the institutional competence in DECC to be able to carry out all of those many powers that they have now given themselves over the years."[38]

> "I think we need to get away from the pretence that we have a market-led system and that the market is going to decide. We need to call a spade a spade and say the decisions are being made centrally. Once that is done, it is then perfectly possible to allow the private sector to deliver, and the private sector is very good at delivering when it is given a clear task … At the moment, we do not have that clarity about what we need for what is a very important aspect underpinning so much else of the society that we need."[39]

33. Some witnesses, however, were less convinced of the case for more planning of this kind. Guy Newey, Head of Policy, OVO Energy, noted that:

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36 Q 186

37 Written evidence from GDF SUEZ Energy UK-Turkey (REI0036)

38 Q 92 (Dr Keith MacLean)

39 Q 93 (Dr Keith MacLean)

> "It is important to put [the Capacity Market] in the wider context of where energy policy has been heading, which is intervention after intervention after intervention, and towards a much more planned generation system … If you move to a situation where the Government are deciding prices on every particular technology—whether it is offshore wind, onshore wind or nuclear power and so on—eventually you are going to have to give everyone a set price, so you make all the decisions in the market. That might give you a very reliable system but it might mean that you are also paying for a lot more generation capacity than you need to."[40]

34. The Secretary of State explained that the Government had intervened in order to tackle two sides of the trilemma—sustainability and security of supply:

> "Your other question was whether or not electricity market reform has seen more intervention. Clearly it has. The first reason for intervening in the market that lies behind EMR, and indeed behind policies before it that were similar but not as well designed, is in my view the need to tackle the challenge of climate change. The market does not cost in the effects, the costs, of climate change, and while you might want to do this in another way, for example through a carbon price or carbon tax—we know the difficulty of designing those both internationally and with a credible level over time—we think that the contracts for difference, which is our intervention on the carbon challenge in the EMR, are a good way of dealing with that problem. They are a targeted intervention.
>
> The other major intervention by the electricity market reform is, indeed, on the security of supply through the Capacity Market. It has been clear for some time that, left to its own devices, the free market was not bringing forward low-carbon capacity or sufficient capacity, so the capacity market within EMR is designed to do that. But it is quite common in the academic literature to find two good reasons for intervening, which have emerged both over history and in different countries, and they are the two I mentioned: the need to deal with the fact that the markets do not price in carbon by themselves and do not have a solution for that—they will just bring in fossil fuels and not low-carbon—and the need to make sure that we have security of supply."[41]

35. We welcome this clear statement from the Secretary of State and the acknowledgment that Britain has effectively moved to a managed electricity market. A policy of decarbonisation makes an entirely liberalised market in the electricity system impossible while low-carbon sources of power are more costly than high-carbon sources. As a result, the Government has chosen to play a major role in planning the electricity system. In light of the pitfalls of central planning, we endorse the Government's embrace of a managed market in which market mechanisms are still used to elicit competitive pricing as far as possible (i.e. the Capacity Market auction).

36. A consequence of the need to reconcile the three components of the trilemma, energy security, sustainability and affordability (see Box 1), is that ultimately it must be for the Government to determine the balance between each of these conflicting objectives. If the Government pursues decarbonisation as an

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40 Q 37 (Guy Newey)

41 Q 186 (the Rt Hon Ed Davey MP)

objective, in line with its legal and international obligations, and at the same time seeks to ensure that power remains available at all times, this will mean higher prices for electricity under the current state of technology. Conversely, if fossil fuel prices were to rise in future, and low carbon technology costs were to fall, then prices could become lower than those for a high carbon electricity system in the medium term. The variables and uncertainties are manifold. The Government, however, should recognise, and more clearly articulate, the strain that will be placed on affordability, as decarbonisation is pursued, and while low-carbon sources of power are more costly than high-carbon sources.

37. **Given its policy objectives, we conclude that the Government has had little choice but to play a greater role in managing the electricity system. We therefore endorse the Government's adoption of a managed market and stress that it is explicitly for the Secretary of State to provide leadership and clarity on responsibilities across the sector. Balancing security of supply, sustainability and affordability (the trilemma) is a first order issue for the Secretary of State. We recommend that the Secretary of State clearly sets out the Government's approach to balancing the trilemma and is clear with Parliament and the public about the pressures which will accrue on affordability under the current state of technology.**

Engineering the future: Viewing the electricity system as a whole

38. We have, above, identified some of the issues with which the Government has been wrestling in recent years and the interventions that it has consequently deemed necessary to make. We were made aware, however, of the need to take a longer view, especially in terms of engineering solutions. As the electricity system undergoes profound changes, it will be increasingly important (it has always been important) to view the system as a whole, as we have tried to do in our inquiry, in order to ensure that an end to end approach is taken, and that a focus on a particular part of the system does not lose sight of the overall design. Dr Harrison, Chair of the Energy Policy Panel, Institution of Engineering and Technology (IET), told us that:

> "… resilience is a system property. It belongs to the whole end-to-end system from large power stations and even their fuels supplies, manufacturing supply chains, everything else through to what happens beyond the electricity meter in consumer premises. One has to think about resilience in the round and not in pieces, because if you think about it in pieces you will tend to end up missing important interactions."[42]

39. Moreover, we heard that viewing the electricity system as a whole is becoming increasingly important because it is anticipated that the system will be subject to far reaching changes: "… we are now in the early stages of a period of profound change. We are not yet in a position to forecast where this will ultimately lead or predict all the problems that will emerge."[43] To elaborate, the IET put it to us that there will be a: "dramatic increase in complexity between now and 2030 as Britain's electricity system is adapted to a low carbon future" and that there are:

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42 Q 1 (Dr Simon Harrison)

43 Written evidence from the Institution of Engineering and Technology (IET) (REI0032)

> "… disruptive changes ahead, which are material in scale. The power networks will have an increasing penetration of automation and intelligent systems, and will deploy entirely new devices featuring power electronics and other advanced, fast-acting control systems. Under these significant changes, the GB System Operator, along with the Transmission Owners and Distribution Network Operators will be faced with a significantly more complex system to operate as a result of the development of Low Carbon Technologies, new market arrangements and increased customer participation."[44]

Professor Mitchell, Professor of Energy Policy at the University of Exeter, used an analogy with telephony to explain the changes that lie ahead. She told us that: "our energy system is still at the equivalent of the simple mobile phone rather than the smart phone stage" and that it was necessary to consider the opportunities and challenges that will emerge as the electricity system makes the transition to a smart energy system—analogous to the profound differences between phones designed simply for making calls vis-à-vis the functionality of today's smart phones.[45]

40. Professor Loughhead, representing the Royal Academy of Engineering, and now Chief Scientific Advisor at the Department of Energy and Climate Change, explained to us that:

> "… one of the issues that we are disappointed about is the fact that it has been obvious for some years that we have needed to take a more active role in looking at what the overall engineering conception of the system is going to be, but there has not been anybody so far who has been in the position to take that responsibility within the UK. What we have been doing is exploiting a system that we have. We can see the looming need to start to design it differently but at present it is not clear who is going to take up that responsibility."[46]

41. In order to address this perceived need for an overall engineering conception of the system, the IET has been developing a case for the establishment of a so-called 'electricity system architect' (SA).[47] This architect would have responsibility for embedding whole systems thinking across the whole electricity system. The IET has noted that while there is, in its view, consensus on the need to view the system as a whole, significant uncertainties need to be resolved:

> "It is fair to say that whilst there is wide industry consensus on the need to introduce effective whole systems thinking, debate continues on the most appropriate institutional response and how this should be shared between government and industry self-regulation. For example, whilst network companies fully appreciate the need for strengthened system integration, they are concerned over the possibility of close government engagement in aspects of their business that require specialist technical knowledge and experience, and which might be more effectively managed,

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44 Supplementary written evidence from the Institution of Engineering and Technology (IET) (REI0052)

45 Q 141 (Professor Catherine Mitchell)

46 Q 2 (Professor John Loughhead)

47 Supplementary written evidence from the Institution of Engineering and Technology (IET) (REI0052)

at least as a first stage, through the development of existing industry governance mechanisms (known as the Code Panels)."[48]

42. This statement broadly reflects the evidence we received. The UK Energy Research Centre (UKERC), for instance, described the proposed role of system architect as "a potentially important new initiative originating within the UK's engineering community."[49] Others, however, expressed concerns about the proposal. Paul Spence, Director of Strategy and Corporate Affairs, EDF Energy, told us:

> "I think we already have three bodies: the Department of Energy and Climate Change, Ofgem and National Grid, all of whom have responsibility for looking across the system as a whole. You also have companies like mine that look across the system as a whole and try to form a view about what it needs and what it is going to look like. Personally, I am certainly not convinced that we need more beyond that."[50]

43. Guy Newey, Head of Policy, OVO Energy, stated:

> "Systems architects are just people making choices based on the information they are giving and without foresight going forward. But they may have the confidence that they have the foresight going forward, so they will say, 'We have looked at everything and it turns out that tidal power or the EPR [European Pressurised Reactors] reactor is the right answer'; and off we go and spend a fortune on it."[51]

44. Dr John Roberts, a fellow of the Royal Academy of Engineering (RAEng), and co-author of the recent RAEng report, *Counting the Cost: The Economic and Social Costs of Electricity Shortfalls*, said:

> "I would say that at the moment we already have Ofgem, we have National Grid, which have nationwide responsibilities. To me it is more an institutional thing. Who would this body be? To whom would they be responsible? Do they override Ofgem? Do they override National Grid? Are they purely advisory? I can see the point perhaps in principle, but the practicalities would be very difficult to work through."[52]

45. The Secretary of State for Energy and Climate Change, Rt Hon Ed Davey MP, expressed some enthusiasm for the proposal, without endorsing it, and suggested that the new energy systems catapult[53] might provide a forum for further examination:

> "I certainly welcome the work that the Institution of Engineering and Technology and its energy panel have done in looking at this concept of the systems architect. That needs further exploration. I am not saying that we are yet convinced that it is the right solution, but I think they are asking

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48 Supplementary written evidence from the Institution of Engineering and Technology (IET) (REI0052)

49 Written evidence from the UK Energy Research Centre (REI0031)

50 Q 43

51 Q 40 (Guy Newey)

52 Q 166

53 The Catapult is due to launch in April 2015. Catapults are technology and innovation centres where industry, scientists and engineers can work together on research and development; they help turn ideas into services and products for the market place.

the right questions, and we would like to see that work in that area and the governance of the system continue.

The Committee will be aware that we have an energy systems catapult as part of the Secretary of State for Business, Innovation and Skills' programme for helping new technology and new challenges to be taken forward and dealt with more speedily. The new systems catapult can definitely explore the thinking behind the systems architect and work with the IET and others on a structured programme of work to explore the potential.

… there are quite a number of players already, whether it is National Grid as the systems operator, Ofgem as the regulator, or DECC as the sponsoring department, so I am not yet convinced that we need a new body to come in. There may well be responsibilities and duties that need to be given to an existing body with an overall shape and role within the government system, but I am not in the market for a whole new set of quangos … The analysis behind the concept of a systems architect is where we need to go. What would it do? Could it be grafted on to one of the existing players? We are certainly not rejecting that. We want to see it explored, but it is relatively early days in working out what that will actually look like."[54]

46. We agree with the Secretary of State and look forward to the new Energy Systems Catapult, or another suitable organisation, exploring the issues which the idea of a system architect raises.

47. **We conclude that it is imperative that the electricity system is viewed as a whole in order to enable effective engineering integration across the electricity system as changes occur. We look forward to analysis from the new Energy Systems Catapult—or another suitable organisation—about how effective decisions can be made in the context of the whole electricity system. This should include examining the thinking underpinning the Institution of Engineering and Technology's proposed 'system architect.' We look forward to receiving progress reports on the findings of this work.**

54 Q 198

CHAPTER 3: WILL THE LIGHTS GO OUT?

48. In this chapter, we consider the issues around short term resilience of the electricity system. The question of "will the lights go out?" is often raised in this context. This is, however, merely short-hand. In the event of a shortage, the lights going out would be the least of our problems. Society's dependence on electricity is becoming ever greater. Today, an electricity shortage has the potential to result in a catastrophic collapse in all modern communications and many vital systems. Recent decades have seen a dramatic increase in society's vulnerability to electricity shortages.

49. In this chapter we give particular consideration to the resilience of the electricity system over this year and next when capacity margins are particularly tight. In addition we extend our analysis through to 2020 by which time the Capacity Market will have come into effect.

50. The electricity system in Great Britain has historically been highly reliable and resilient. As the Institution of Engineering and Technology (IET) told us, the last time electricity resilience was an issue was the three day week in the 1970s.[55] National Grid told us that, at 99.99995%, the transmission system for England and Wales was the most reliable network in Europe.[56]

The Narrowing Capacity Margin

51. As noted in Chapter 1 of this report, the capacity margin forecast for this winter (2014/15) and next (2015/16) was particularly tight. Here we examine how this situation could have arisen and what the implications are for resilience of the electricity system. Although there are many factors influencing the narrowing capacity margin, a central issue is the closure of old power stations, coupled to insufficient investment in new generation capacity.[57] Box 2 provides further information about how the capacity margin, and corresponding Loss of Load Expectation (LOLE), are calculated. A lower capacity margin or higher LOLE equates to a less resilient system.

Box 2: The Capacity Margin and Loss of Load Expectation (LOLE)

The **capacity margin** is the *proportion* by which the total expected available electricity generation exceeds the maximum expected level of demand *at the time at which that demand occurs*. It acts as an insurance against "occasional unexpected losses of power or surges in demand" and is normally expressed as the percentage calculated by:[58]

$$\textit{Capacity Margin (\%)} = \frac{\textit{total available capacity - peak demand}}{\textit{peak demand}} \times 100$$

Total available capacity can be defined in two ways:

55 Written evidence from the Institution of Engineering and Technology (IET) (REI0032)

56 Written evidence from National Grid (REI0017)

57 RAEng, *GB Electricity Capacity Margin* (October 2013): http://www.raeng.org.uk/publications/reports/gb-electricity-capacity-margin [accessed February 2015]

58 *Ibid.*

1. In the past the **gross capacity margin** was calculated based on the total amount of electricity which could theoretically be generated at any one time.
2. Now the **de-rated capacity margin** is more commonly used.[59] This is the average excess of available generation over peak demand. The de-rated capacity margin takes account of the fact that not all generation capacity will run at its theoretical maximum all of the time. This is particularly important for renewable generation, where the output at peak times can be considerably lower than the theoretical maximum.[60] This metric de-rates each generation type by a factor reflecting the "statistically expected level of reliable availability from that plant type."[61] Ofgem typically uses winter de-rating factors of:
   - Coal/biomass: 88%
   - Gas: 85–92%
   - Oil: 82%
   - Nuclear: 81%
   - Hydro/pumped storage: 84–96%
   - Wind: 17–24% [62]

It should be noted that gross capacity margins cannot be directly compared to de-rated capacity margins. As a broad reference, however, a 20% gross capacity margin, which was the typical aim in the past,[63] has been likened to a de-rated capacity margin of 4–5%, although this would depend on the precise plant mix and the de-rating factors chosen.[64] In this report we use the de-rated capacity margin unless stated otherwise.

Although National Grid and Ofgem still report on the capacity margin, Ofgem argues that the capacity margin is: "not a good indicator of risk, as it is an average value and provides no information about the variability around this average value."[65] Therefore, another measure, **Loss of Load Expectation** (**LOLE**) is also used. As described by Ofgem:

"The LOLE is the average expected number of hours per year in which supply is expected to be lower than demand under normal operation of the system. This means the number of hours per year when we expect National

59 RAEng, *GB Electricity Capacity Margin* (October 2013): http://www.raeng.org.uk/publications/reports/gb-electricity-capacity-margin [accessed February 2015]; Written evidence from The Institution of Engineering and Technology (IET) (REI0032)

60 Due to e.g. unfavourable weather conditions.

61 RAEng, *GB Electricity Capacity Margin* (October 2013): http://www.raeng.org.uk/publications/reports/gb-electricity-capacity-margin [accessed February 2015]

62 Ofgem, *Electricity Capacity Assessment Report 2013* (June 2013): https://www.ofgem.gov.uk/ofgem-publications/75232/electricity-capacity-assessment-report-2013.pdf [accessed February 2015]

63 Of the Central Electricity Generating Board (CEGB), former nationalised owner and operator of the England and Wales electricity network and generation (1957–1990).

64 RAEng, *GB Electricity Capacity Margin* (October 2013): http://www.raeng.org.uk/publications/reports/gb-electricity-capacity-margin [accessed February 2015]

65 Ofgem, *Electricity Capacity Assessment Report 2014* (June 2014): https://www.ofgem.gov.uk/ofgem-publications/88523/electricitycapacityassessment2014-fullreportfinalforpublication.pdf [accessed February 2015]

> Grid to have to use mitigation actions, including the use of the new balancing services. The LOLE is still not a measure of the expected number of hours in which customers may be disconnected as National Grid is expected to use other mitigation actions ahead of controlled customer disconnections."[66]

52. As part of Electricity Market Reform, the Government set a Reliability Standard of 3 hours LOLE per year. This means that the LOLE over the course of the year should not exceed 3 hours. As EDF Energy explain, however: "This does not mean 3 hours of blackouts per year; it means that, on average, there may be 3 hours per year when supply would not match demand and exceptional measures would be required to avoid significant effects on customers."[67]

53. The capacity margin is affected by events, such as the technical failure of power stations. In June 2014, Ofgem forecast a de-rated capacity margin of 6.7% and a LOLE of 0.5 hours for winter 2014/15.[68] The capacity margin was expected to fall further to a low of 3% in 2015/16 before recovering in subsequent years.

54. A series of unexpected power station outages and closures followed. In October 2014 National Grid revised the forecast for winter 2014/15 to a capacity margin of 4.1% and a LOLE of 1.6 hours.[69] A LOLE of 1.6 hours still comfortably meets the 3 hours LOLE Reliability Standard. National Grid were of the view, however, that there was still considerable uncertainty regarding potential further power station closures and the maintenance schedule of key generators.[70] A decision was therefore taken[71] to use New Balancing Services (NBS) to manage the risk by procuring additional capacity. It proved necessary to put NBS in place as the Capacity Market will not begin to operate until 2018. As National Grid explain, NBS comprised:

> "… two additional system balancing tools (Demand Side Balancing Reserve and Supplemental Balancing Reserve). These balancing tools will only be used as a last resort in the unlikely event of a shortfall of generating capacity in the electricity market and allow us to procure additional capacity over the winters of 2014/15 and 2015/16."[72]

55. The first of these tools, Demand Side Balancing Reserve (DSBR), provides contracts to large electricity consumers who are willing to reduce electricity consumption, or provide generation from backup generators, during times of peak demand (between 4 and 8 pm on weekday evenings in the winter).

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66 Written evidence from Ofgem (REI044)

67 Written evidence from EDF Energy (REI0030)

68 Ofgem, *Electricity Capacity Assessment Report 2014* (June 2014): https://www.ofgem.gov.uk/ofgem-publications/88523/electricitycapacityassessment2014-fullreportfinalforpublication.pdf [accessed February 2015]; National Grid, *Winter Outlook 2014/15* (October 2014): http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=36714 [accessed February 2015]

69 National Grid, *Winter Outlook 2014/15* (October 2014): http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=36714 [accessed February 2015]

70 *Ibid.*

71 Following consultation between National Grid, Ofgem and DECC.

72 Written evidence from National Grid (REI0017)

Consumers entering into such contracts receive an upfront payment and further payments in the event that National Grid makes use of the service.[73]

56. The Supplemental Balancing Reserve (SBR) provides contracts to generators when they commit to making a power station, which would otherwise have been closed or mothballed, available in winter.[74]

57. For winter 2014/15, National Grid procured additional capacity using New Balancing Services. As Mike Calviou from National Grid explained, this has helped to boost the capacity margin from 4.1% to 6.1%:

> "For this coming winter, the market has delivered a 4.1% de-rated margin. We have taken action with our supplemental balancing reserve purchases to increase that to a 6.1% margin, and we think that is a level that we can manage the system with this winter."[75]

58. Box 3 provides information about the capacity margins for 2014/15 with and without NBS. For winter 2014/15 National Grid contracted a total of 319 MW of DSBR across 431 individual sites with businesses, such as Tata Steel and Flexitricity,[76] at a cost of £2.25 million.[77] A total of 2025 MW SBR was contracted with two gas power stations and one oil fired power station[78] at a cost of £29.5 million.[79]. Together these New Balancing Services provide an additional, de-rated capacity of 1.1 GW.[80] The forecast cost of New Balancing Services for winter 2014/15 was £31.75 million at a unit cost of £19.3/kW.[81] Further costs would have been incurred if this capacity had actually been used. As the Rt Hon Ed Davey MP, DECC Secretary of State, told us, so far National Grid has not needed to make use of this additional capacity:

> "National Grid has purchased 1.1 gigawatts of balancing reserve to support the system. It has not had to use that at all, because we have got nowhere near a problem, but it is there; it sits outside the market and National Grid can use it if we have a problem at peaks. We do not anticipate that, but it is there as a sort of insurance policy."[82]

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73 Written evidence from National Grid (REI0017)

74 *Ibid.*

75 Q 54

76 National Grid, 'Companies win contracts for reducing power demand': http://www2.nationalgrid.com/mediacentral/uk-press-releases/2014/companies-win-contracts-for-reducing-power-demand/ [accessed February 2015]

77 This includes £1.1 million set up fees, £150,000 administration fees and an estimated £1 million of testing costs.

78 National Grid, *SBR Winter 2014/15—Contracts Confirmed* (November 2014): http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=36915 [accessed February 2015];

79 This includes capability fees of £23.5 million and estimated warming/testing costs of £6 million.

80 The 1.1 GW of additional capacity takes the de-rated capacity margin from 4.1% to 6.1%.

81 Supplementary written evidence from National Grid (REI0060)

82 Q 188 (the Rt Hon Ed Davey MP)

59. For winter 2015/16, National Grid intends to put contracts in place for an additional 1.8 GW of de-rated capacity.[83] After this the Capacity Market will come into effect.

Box 3: Key Data

- The total amount of electricity, which was generated in the UK in 2013, was **359 TWh**. The total demand was **374 TWh**. Interconnectors made a net contribution of **14.4 TWh**.[84] The amount consumed, after transmission losses and consumption within the energy industry are taken into account, was **317 TWh**.[85]
- Peak electricity demand in Great Britain in 2013/14 was **54 GW**.[86]
- For 2014/15 the forecast mid-winter generation capacity was **71.2 GW**. When availability and historic performance was taken into account, this was de-rated (see Box 2) to **58.2 GW**.[87]
- The forecast Average Cold Spell peak de-rated demand margin was **4.1%** with a Loss of Load Expectation (LOLE) of **1.6 hours**.
- Once the New Balancing Services were included, the de-rated margin was **6.1%** with a LOLE of **0.6 hours**.

Units

Power (measured in kilowatts, kW) is the rate at which energy (measured, for example, in joules or kilowatt hours, kWh) is generated or used:

power = energy ÷ time

1,000,000,000 kilowatts (kW) = 1,000,000 megawatts (MW) =1,000 gigawatts (GW) = 1 terawatt (TW)

60. As a result of the actions taken by National Grid to improve the capacity margin, domestic consumers are highly unlikely to see power shortages. During our inquiry we heard that although the capacity margin had become tight, the right steps have now been taken to ensure supply meets demand. As Ofgem told us: "We are confident that National Grid has the right levers to keep the lights on."[88] Professors Newbery and Grubb noted: "there is no 'cliff edge' at which the lights go out, but rather an increasing array of options for managing tight conditions."[89] There is no reason to expect that these tools will

83 Q 188 (the Rt Hon Ed Davey MP); National Grid, *SBR and DSBR Market Update* (December 2014): http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=38323 [accessed February 2015]

84 DECC, *Digest of United Kingdom Energy Statistics 2014* (July 2014): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/338750/DUKES_2014_printed.pdf [accessed February 2015

85 The difference between demand and consumption is accounted for by the 29 TWh used within the energy industry and 27 TWh of losses.

86 Ofgem, *Electricity Capacity Assessment Report* 2014 (June 2014): https://www.ofgem.gov.uk/ofgem-publications/88523/electricitycapacityassessment2014-fullreportfinalforpublication.pdf [accessed February 2015]

87 National Grid, *Winter Outlook 2014/15* (October 2014): http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=36714 [accessed February 2015]

88 Written evidence from Ofgem (REI0044)

89 Written evidence from Professor David Newbery and Professor Michael Grubb (REI0026)

not be effective in keeping the lights on. Indeed, witnesses praised National Grid's professionalism in balancing the system.[90]

61. The Secretary of State, the Rt Hon Ed Davey MP, assured us that the lights would stay on:

> "We are expecting there to be about 1.8 gigawatts of supplemental balancing reserves for 2015–16. On the basis that that goes ahead, I am sure that the lights will stay on not only this winter but next winter as well."[91]

62. This is not the impression one might get from coverage in the media, where the question of 'will the lights go out?' is often posed. In answer to this question, **we conclude that because of the measures put in place by National Grid, the lights are unlikely to go out due to insufficient generation capacity.**

63. The real question is not about whether the lights will go out, but whether the measures taken to make sure they stay on are adequate, whilst not being over cautious, and effectively addressing all three sides of the trilemma. Professor Helm CBE suggested that putting in place last minute measures, such as New Balancing Services, to balance the system, would be costly. He argued that better forward planning should have been in place:

> "There will be a cost and a price: if you do things in a hurry short term, you are bound to have additional costs. But this does not detract from the point that you want never to be in this situation again. You want to get to a situation where you have a comfortable margin. Any reasonable, large-scale economy like the British economy, with its reliance on electricity, is vastly better off in a world in which it is quite content and has a bit of fat in its capacity margin so it does not have to worry about these kind of problems, which play down on the aggregate price in the market. To run around saying, 'Thank God we only have 4% [capacity margin], at least we are not spending money on mothballed power stations' is not a state of affairs that we want to get into."[92]

64. The Rt Hon Ed Davey MP argued that the measures were not last minute:

> "First of all, it has not been last minute … These plans have been developed since the coalition came to power. I do regret that there has been a poor legacy, but we have been working on it. If you look through the history of our consultation and our announcements, they have not been just in the last week, month or year, but over a period of years. So I do not call that the last minute. Of course they come at a cost—absolutely. My job has been to make sure that we minimise that cost."[93]

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90 Q 50 (Professor Dieter Helm); Q 165 (Dr John Roberts)

91 Q 188 (the Rt Hon Ed Davey MP)

92 Q 50

93 Q 188 (the Rt Hon Ed Davey MP)

The Government estimates that procuring New Balancing Services added: "less than £1 on the average household bill"[94] in the year 2014/15. This represents an increase of less than 0.2% on an average electricity bill of £586.[95]

65. As Professor Helm noted, the situation regarding the capacity margin could have easily been much worse. Demand for electricity has declined substantially since the economic crisis began. If demand had continued to grow, capacity margins could have been much tighter: "We got lucky in one respect. We have crashed the economy—not deliberately, but the consequence of that is to buy us 10 years of time."[96]

66. Irrespective of how this situation has arisen, it has been known for some time that ageing power stations would close and appropriate, long term action to ensure that capacity margins remain healthy has been late in arriving. As Professor Helm commented:

> "It is a quite extraordinary state of affairs for a major industrialised economy to find itself even debating whether there is a possibility that the margins may not be sufficient in electricity to guarantee supply, particularly in a context in which electricity is increasingly important to the economy, and where information technology and so on depend absolutely crucially on a continuous supply."[97]

67. It is our view that it is not sound policy to sail so close to the wind. It seems that successive governments should have anticipated the shrinking capacity margin earlier and taken steps to address it. We note that without the economic downturn the situation could have been more critical. Our aim is not, however, to attribute blame for past failures, but rather to ask whether there is now sufficient rigour and planning to avoid such situations in the future.

The Capacity Market

68. To provide enough capacity in future, the Government has now introduced a Capacity Market (CM) which will operate from 2018. It proved necessary to put New Balancing Services in place as an interim measure ahead of the Capacity Market coming into effect. An explanation about how the Capacity Market operates is provided in Chapter 1 of this report.

69. During the course of the inquiry, we heard that many were supportive of the Capacity Market.[98] Others, however, were less enthusiastic:

> "We remain pretty sceptical of the need for a capacity mechanism. As I said before, historically the market signal has been able to provide the signal for new generation. There is an open question about whether you have a heavily interventionist government policy making decisions all over the place that you need yet more intervention, but the question is whether

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94 Q 188 (Jonathan Mills)

95 DECC, *Estimated impacts of energy and climate change policies on energy prices and bills*. (November 2014): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/371637/prices_and_bills_report_2014.pdf [accessed February 2015]

96 Q 50

97 Q 44

98 Written evidence from EDF Energy(REI0030); Written evidence from Energy UK (REI0034); Written evidence from the Nuclear Industry Association (NIA) (REI0020)

you try to roll back that intervention or intervene anymore. It seems very odd that we are providing a subsidy to coal-fired power stations on the one hand and at the same time spending a lot of money trying to reduce carbon emissions on the other hand. Reducing carbon emissions is a very sensible aim but doing it by keeping coal power stations running seems extremely odd. The effect of a capacity mechanism will be to add cost but that is back to that political choice about what price you want to pay for extra capacity, and the Government have decided that they think customers are willing to pay."[99]

70. Great Britain is not the only country to introduce a capacity mechanism. Capacity mechanisms are increasingly being considered in Europe, although different countries are taking different approaches.[100] In the UK Capacity Market the Government defines the amount of capacity needed and a competitive auction is held to determine the price. An alternative approach is the capacity payment, where the price is pre-determined by a central authority. A few European countries have established mechanisms, including Ireland, Spain and Greece.[101] A Capacity Market is being set up in France for delivery of capacity in 2016–17.[102] Professor Mitchell from the University of Exeter considered that the Danish System Operator Energienet had a better system in place than Great Britain's Capacity Market for ensuring sufficient capacity:

"If they feel that they need some more capacity of some other capability requirement, Energinet the [Danish] system operator, is able to say, "We need 300 megawatts of this", and then that can be competitively put out to tender if you need it. Then, if you do not need it, you do not have to tender for it, whereas our capacity mechanism is just based on giving out this money, even though things change all the time and it may be completely unnecessary, and it is the customers who pay in the end."[103]

71. The first capacity auction in Great Britain, which procured capacity for 2018, concluded on 18 December 2014. This auction procured 49 GW of additional capacity at £19.40/kW with a total cost of nearly £1 billion.[104] As shown in Figure 4, fossil fuel power stations accounted for in the region of 68%[105] of the capacity procured. Procuring such a large percentage of capacity from fossil

99 Q 37 (Guy Newey)

100 Leonie Meulman and Nora Méray, *Capacity Mechanisms in North West Europe* (November 2012): http://www.clingendaelenergy.com/inc/upload/files/Capacity_mechanisms.pdf [accessed February 2015]

101 ACER, *Opinion of the Agency for the Cooperation of Energy Regulators no. 05/13 on Capacity Markets* (2013): http://www.acer.europa.eu/Official_documents/Acts_of_the_Agency/Opinions/Opinions/ACER%20Opinion%2005–2013.pdf [accessed February 2015]; Ben Caldecott and Jeremy McDaniels, *Stranded generation assets: Implications for European capacity mechanisms, energy markets and climate policy* (2014): http://www.smithschool.ox.ac.uk/research-programmes/stranded-assets/Stranded%20Generation%20Assets%20-%20Working%20Paper%20-%20Final%20Version.pdf [accessed February 2015]

102 Thomas Veyrenc, Réseau de transport d' électricité , 'A capacity market in France: status of discussions and future steps' (presentation), (24 April 2014): http://www.wec-france.org/DocumentsPDF/3rd_european_energy_forum/T.Veyrenc.pdf [accessed February 2015]

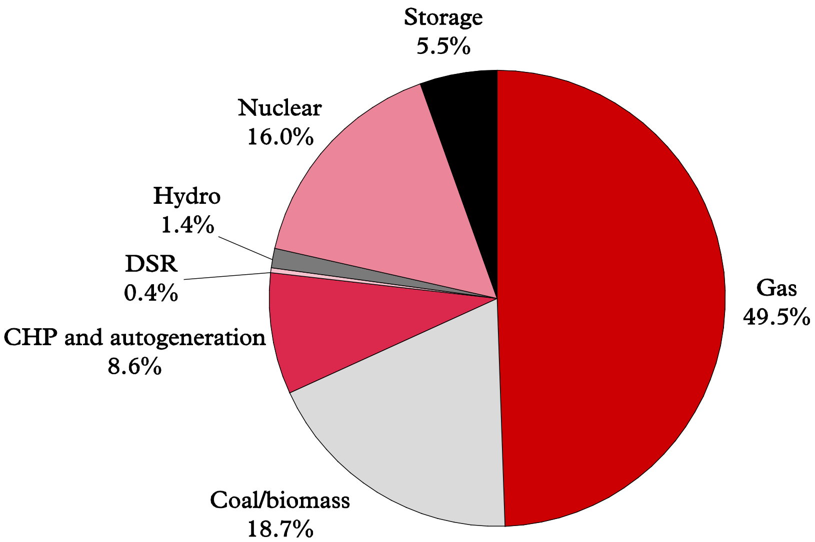
103 Q 144

104 National Grid, *Final Auction Results* (January 2015): https://www.emrdeliverybody.com/Shared%20Documents/Final%20Auction%20Results%20Report_v3.pdf [accessed February 2015]

105 This figure includes gas and coal/biomass (for which disaggregated figures were not reported). It does not include CHP and autogeneration, although much of this is gas-fired.

fuel generation is incompatible with the Government's wider policy aims to decarbonise electricity supply.

Figure 4: Capacity Procured in the Auction by Technology Type



Source: National Grid, Final Auction Results (January 2015): https://www.emrdeliverybody.com/Shared%20Documents/Final%20Auction%20Results%20Report_v3.pdf [accessed February 2015]

Capacity procured for 2018 in the 2014 capacity auction. Gas includes Combined Cycle Gas Turbine (CCGT) (45.2%) and Open Cycle Gas Turbine (OCGT) and reciprocating engines (4.3%). CHP = Combined Heat and Power. DSR = Demand Side Response.

Resilient networks

72. Generation capacity is not the only factor affecting resilience. Investment in the resilience of the network itself is also important. Ofgem ensures that transmission and distribution network operators are making sufficient investment in the networks using its RIIO price controls as described in Chapter 1. As Ofgem explain:

> "RIIO stands for "revenue", which is the revenue that the companies get from running the networks, which is determined by a set of "incentives, innovation and outputs". We are trying to ensure that there was a real emphasis not just on how much revenue the companies are allowed but on what they have to deliver on that revenue … As I said before, they also have to pay out to customers under the guaranteed standards. That puts incentives on to the companies to make their networks as resilient as possible and to respond when issues arise."[106]

73. Ofgem has recently completed a review of the RIIO price controls for electricity distribution networks. Dr John Roberts, FREng, appeared confident that this would allow sufficient investment in distribution networks.

> "I think we are spending a sufficient amount on the distribution network. We have just completed the price review for the distribution network with Ofgem, and that will come into effect on 1 April [2015]. I think that makes

[106] Q 182 (Maxine Frerk)

> sufficient allowance for investment in the network to maintain the resilience of the network."[107]

Costs and benefits

74. There is, of course, a trade-off between the costs of investing in resilient networks and in generation capacity and the benefits of doing so. The electricity system could always be made more resilient through additional investment, but it can never be infallible:

> "… there are all sorts of things that can go wrong. They can be mitigated, but it is impossible to avoid any form of risk. At the end of the day you have to balance issues like affordability and resilience. There are a whole set of issues there to be balanced."[108]

75. The decision of how to balance resilience and affordability must ultimately be taken by the Government. As Guy Newey from OVO told us:

> "Ultimately the decision of how reliable you want the system to be is a political decision. Make no mistake, energy companies want to keep supplying energy to customers for quite obvious financial reasons but also because it is the right thing to do. The Government have ultimately got to decide whether they want to have a system that is resilient to a one in eight year, a one in 100 or a one in 200. The more resilient you make the system the more expensive you make the system and the more gold-plating you have. You will never be able to completely remove risk of course, but that ultimately is a political decision about balancing costs overall to a system and the ability of bill payers and taxpayers to match those."[109]

76. The decision about how much to invest in resilience depends on how much consumers are able or willing to pay:

> "Steps have been taken by the distribution companies to increase resilience to severe weather events, including flood mitigation, use of insulated overhead line conductors, rebuilding lines to a heavier construction specification, increasing lightning surge withstand capability, and automated switching to isolate faults and restore supplies. Resilience could be further improved by even greater levels of investment (with resulting increases in consumer prices which Ofgem's consumer surveys have indicated would not be supported) but, whilst such events are highly inconvenient for those consumers affected, they do not threaten the integrity of the electricity system as a whole."[110]

77. As noted above, Professor Helm argued that putting in place measures, such as New Balancing Services, to ensure a sufficient capacity margin will be costly. There are also concerns about the costs of the Capacity Market as a longer term measure to guarantee capacity. Fundamentally, there are arguments about what capacity margin is appropriate and so how much

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107 Q 154

108 Q 18 (Sarah Rhodes)

109 Q 35 (Guy Newey)

110 Written evidence from the Institution of Engineering and Technology (IET) (REI0032)

additional capacity should be procured. Professor Helm argued that running a system with low capacity margins increases costs:

> "If you run a system at a 4% or 2% margin the price will be higher. Everyone will pay a higher electricity price because the price needed to bring the market into equilibrium is higher, because the stuff is scarce."[111]

78. Professor Newbery from the University of Cambridge, however, argued that while a healthier capacity margin might bring prices down, there may be consequences of this which need to be considered:

> "… if you over-procure capacity then the nominal cost is about £2.5 billion but the net cost to consumers is less than that because the prices will be lower. A larger capacity margin means lower prices in the wholesale market. But that has consequential effects. Two of them are that the cost of supporting renewables goes up because the difference between the wholesale price and the strike price [under Contracts for Difference] increases. If that goes up then the Levy Control Framework[112] restricts the amount of renewables you can put on the system, so there are adverse consequences for one of the main targets of the electricity market reform. If we lower the price in this country relative to other countries the economics of building interconnectors is undermined somewhat and, since renewable generation is imperfectly correlated the wider the area over which you trade, that disadvantages the penetration of renewable generation. It is true that the prices may come down but it would be unwise to ignore the adverse consequences of that."[113]

79. Professor Helm suggested that a capacity margin of more than 10% was needed.[114] National Grid, however, were sceptical about whether such a high margin was necessary:

> "… over 10% on a de-rated basis would be a very, very comfortable margin, which I would be surprised if the market was consistently delivering because at that level there would be some generators that would probably never run."[115]

80. There does, however, seem to be uncertainty as to whether the current margins are enough, particularly if the electricity system experiences a high-impact, low-probability event. Dr Roberts described a rare event of this type as a 'Black Swan' event:

> "As far as the supply is concerned, I would have the concern that the supply margin is quite small now … I think what we are worried about are the Black Swan-type events that suddenly happen and whether we have sufficient generation. I would argue perhaps that we do not, but—and this

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111 Q 50

112 The Levy Control Framework was put in place to control the costs to consumers of its energy and climate change policies. Rather than funding these initiatives directly, the Government obliges energy companies to do so. The costs are then recovered through consumer bills. To control these costs the Treasury, through the Levy Control Framework, places a cap the amounts that can be raised and spent through this mechanism.

113 Q 71

114 Q 50 (Professor Dieter Helm)

115 Q 54 (Mike Calviou)

is, I think, the core of the report that we have just produced—we do not really have a good sense of what the costs would be if we did have those sorts of outages: hence, we do not have a benchmark against which to judge how much we should spend, because system security comes at a price."[116]

81. To provide a comparison, EDF Energy supplied us with information about the capacity margin in France.[117] EDF Energy noted that it was not straight forward to compare the capacity margins between the two countries, as peak demand in France is very sensitive to cold weather. In France, LOLE is therefore the preferred measure. As shown in Table 1, France has a higher forecast LOLE for each year through to 2018/19. As Professor Newbery told us: "We [GB] have the same loss of load expectation standard [three hours] as France and Germany. Belgium has two and a half times as high."[118] Meanwhile, the Republic of Ireland aims for a LOLE of 8 hours per year and the Netherlands aims for 4 hours per year.[119]

Table 1: France and UK comparison (LOLE)

France	**2014/15**	**2015/16**	**2016/17**	**2017/18**	**2018/19**
Expected energy unserved	3.3 GWh	15 GWh	23 GWh	14 GWh	9 GWh
Loss of load expectation	1h	4h	5h45	4h	2h30
Surplus or deficit of capacity	2,900 MW	–900 MW	–2,000 MW	–800 MW	500 MW
Great Britain	**2014/15**	**2015/16**	**2016/17**	**2017/18**	**2018/19**
Expected energy unserved	0.5 GWh	4.2 GWh	0.8 GWh	0.3 GWh	1.9 GWh
Loss of load expectation	36mins	3h48	54mins	18mins	1h48
Surplus or deficit of capacity	1,659 MW	–224 MW	1,225 MW	2,103 MW	465 MW

Source: Supplementary written evidence from EDF Energy (REI0053).

It should be noted that for Great Britain, the LOLE provided for 2014/15 is the LOLE following the procurement of additional capacity by National Grid using New Balancing Services (NBS). The LOLE presented for 2015/16 does not take NBS into account.

82. The question therefore remains of what the capacity margin for Great Britain should be and whether the Government is seeking to procure the right amount

116 Q 154

117 Supplementary written evidence from EDF Energy (REI0053)

118 Q 73 (Professor David Newbery)

119 DECC, *Annex C: Reliability Standard Methodology* (2013): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/223653/emr_consultation_annex_c.pdf [accessed February 2015]

of capacity through the Capacity Market. Professor Newbery considered that the Government is being overcautious:

> "We think that understandably perhaps politicians, and particularly Ministers, are so nervous about the concept of the lights going out—and in particular the Daily Mail-type views that that might happen—that they are overcautious, and that has high costs …"[120]

83. Professors Newbery and Grubb have undertaken an analysis, which suggests that the Government may be over procuring capacity, in part because it has not taken the potential contribution of interconnection with other countries into account:

> "We argue costs can be substantially reduced by deferring some of the associated auctions. At the heart of this is the (somewhat unfashionable) conclusion that the UK electricity is more resilient to the risk of "capacity shortfall" than widely assumed. Our analysis concludes that 53.3GW is likely to be excessive, particularly *but not exclusively* in its (lack of) assumed contribution from interconnectors. Political fear of 'the lights going out' can easily become a catch-all argument for excessive procurement, and associated subsidy to incumbent generators."[121]

84. We also heard that there is a lack of information about the amount of backup generation which is available. Such backup generation could potentially participate in the Capacity Market:

> "In addition, there is large capacity of industrial backup generation, mostly diesel—the only estimate we found was an estimate of 20GW, a huge volume which if correct, and made available at times of peak need, would negate any significant risk of capacity shortfall; the apparent lack of any official estimate of this capacity appears to be an important lacunae which should be corrected as a priority."[122]

85. Professor Grubb noted that there appeared to be no firm published statistics on the amount of industrial backup available, but suspected it could play a considerable role in providing capacity. [123]

86. Dr Roberts considered that it would be useful to establish a national inventory of emergency power:

> "It would be a good thing [to establish a national inventory of available emergency power]. Nobody has done it. It is starting to happen. There are commercial organisations out there now that are in contact with large organisations. For example, some of the big supermarkets all have back-up generation in their stores.
>
> Aggregating all of that, they can sell that to the electricity generators as an amount of back-up generation that could be available, and that can be sold to the generators as an economic proposition: "You pay us the money

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120 Q 70 (Professor David Newbery)

121 Written evidence from Professor David Newbery and Professor Michael Grubb (REI0026)

122 *Ibid.*

123 Q 72 (Professor Michael Grubb)

and we can bring this back-up generation into play". It is beginning to happen on a commercial basis. But some kind of index or database right across the UK of the back-up generation to my mind does not exist, and it would be a very useful thing if it did."[124]

87. The Government decided how much capacity to procure through the Capacity Market based on the newly introduced Reliability Standard of 3 hours LOLE. As the Government explained, the Reliability Standard was introduced: "primarily to inform how much capacity to buy in the capacity market."[125] The Reliability Standard is intended to trade off: "the cost of additional capacity against the potential costs of disruption."[126] It aims to provide security of supply at a level the consumer is able and willing to pay for.

88. This raises the question of how the Reliability Standard of 3 hours LOLE was arrived at. The Reliability Standard was defined based on the Value of Lost Load (VoLL). As EDF Energy explained:

> "VoLL is the price that customers would be willing to pay to avoid losing electricity supply. In practice, of course, this price varies between different customers and between different times; nevertheless, it provides a useful guide to determine how much money should be spent to deliver security of supply."[127]

89. There are different ways of measuring the potential costs of electricity shortfalls and there is some debate about which method is most appropriate. Professors Grubb and Newbery questioned whether the VoLL, used to calculate the Reliability Standard, is appropriate:

> "The 'Loss of load probability' is also set on the basis of security standard which in terms of the estimated Value of Lost Load (VoLL) is likely to be excessive from a purely economic standpoint, as we explain in our paper, because it reflects estimates of domestic VoLL but is then applied in practice to industrial VoLL."[128]

90. In 2013, London Economics published a report on the VoLL.[129] This used a 'stated preference' approach, where consumers were asked how much they were hypothetically willing to pay to avoid an electricity outage or conversely how much they were willing to accept to undergo an outage. The VoLL arrived at in this report was used by the Government to set the Reliability Standard of 3 hours LOLE.[130] This VoLL is based on the value for domestic consumers and small and medium enterprises (SMEs). It does not include large commercial and industrial consumers because: "they are assumed either to be

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124 Q 158

125 Q 21 (Andy Shields)

126 Q 25 (Andy Shields)

127 Written evidence from EDF Energy (REI0030)

128 Written evidence from Professor David Newbery and Professor Michael Grubb (REI0026)

129 London Economics, *The Value of Lost Load (VoLL) for Electricity in Great Britain* (July 2013): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/224028/value_lost_load_electricty_gb.pdf [accessed February 2015]

130 DECC, *Annex C: Reliability Standard Methodology* (2013): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/223653/emr_consultation_annex_c.pdf [accessed February 2015]

able to participate in the capacity market through demand side response, or else to be able to change their electricity use in response to price signals."[131]

91. In November 2014, the Royal Academy of Engineering published a report which considered the costs of electricity outages and how to measure VoLL.[132] The report describes three different methods of calculating the cost of an outage to consumers: stated preference, revealed performance and economic modelling. Commenting on the approach taken by London Economics, the report stated: "The choice experiments were conducted in a highly rigorous fashion; however, they represent just one possible method among a number of options, and are subject to the uncertainties inherent in stated preference methods."[133]

92. The Royal Academy of Engineering acknowledged that it is less than ideal to base cost-benefit decisions on such uncertain estimates, but noted that considerable further research would be needed to develop a more robust assessment method.[134] Dr Roberts, a co-author of the report, told us that further research was needed into the costs of shortfalls in electricity supply:

> "I think we need to do a lot more research. Very little research has been done in this country, as our report points out. There has been one Ofgem inspired piece of research, which was done by London Economics in 2013. That is the only piece that we could find in this country. The rest of it has been done elsewhere in western Europe. We do need to do more research: a combination of trying to establish what the cost would be for individual consumers, small businesses and large businesses, but also looking at what has happened in the real world—at the significant events that have happened elsewhere, both in Europe and in other parts of the world, and after the event to get a hard database of evidence."[135]

93. Dr Roberts emphasised the need for future large scale investment across the whole electricity system in both generation and in networks, and the need to communicate the case for such investment more effectively with the public:

> "For me, the most important point is to make the public at large aware of the fact that we need to make substantial investment in our electricity infrastructure. Apart from the decarbonisation point, which I put to one side, simply put we have an infrastructure that is ageing. Many of our power stations were built in the 1960s with an economic theoretical life of 30 years, which is now well exceeded. Ditto a lot of our distribution networks were built in the 1960s, again with an economic life of 20 to 30 years. So we need to invest a lot of money in our network as a whole to make it more resilient, and we need to communicate that message to the

131 DECC, *Annex C: Reliability Standard Methodology* (2013): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/223653/emr_consultation_annex_c.pdf [accessed February 2015]

132 RAEng, *Counting the cost: the economic and social costs of electricity shortfalls in the UK* (November 2014): http://www.raeng.org.uk/publications/reports/counting-the-cost [accessed February 2015]

133 London Economics, *The Value of Lost Load (VoLL) for Electricity in Great Britain* (July 2013): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/224028/value_lost_load_electricty_gb.pdf [accessed February 2015]

134 RAEng, *Counting the cost: the economic and social costs of electricity shortfalls in the UK* (November 2014): http://www.raeng.org.uk/publications/reports/counting-the-cost [accessed February 2015]

135 Q 160

public at large: they may not like it but electricity is going to get more expensive if you want to enjoy the level of resilience that you have enjoyed to date."[136]

94. Additionally, on the point of communicating with the public, Dr Roberts stated:

> "At the moment the public at large are very sensitive to electricity prices, almost to the point, I think, where they say, 'I am paying this much a year for my electricity. I expect you to make sure that it is there all the time. That is what I am paying for, am I not?' Saying, 'No, you have to pay some more now to make sure it is there', might not go down very well, even though it may be entirely justified in technical and economic terms."[137]

95. There has been much discussion, and media coverage, around high energy prices in the UK. Indeed, Ofgem has referred the retail energy market to the Competition and Markets Authority for investigation. As shown in Figure 5, however, compared with other EU countries, the price paid by consumers in the UK for electricity is not particularly high. Although the pre-tax electricity prices in the UK are amongst the highest, the overall cost is kept down as taxes in the UK are low relative to those in other countries.

96. Making comparisons between different countries is, however, always difficult owing to differences in reporting criteria. The UK figure for taxes includes only VAT, which is currently set at 5%, the lowest rate allowed under EU regulations.[138] In Germany, for example, VAT on electricity is set much higher at 19%. This does not, however, account in full for the higher taxes paid by domestic consumers in Germany. In addition to VAT, Germany's tax figure includes other charges such as 'electricity tax' and 'renewables levies,' whereas in the UK the costs of energy and climate change polices are included as an integral part of pre-tax electricity prices.[139] According to analysis by DECC, these costs accounted for 15% of the average domestic electricity price (including tax) in 2014.[140] Based on their central fossil fuel price scenario, DECC estimates that this will increase to 27% in 2020 and 29% in 2030 (see Table 2, para. 217).

97. UK consumer prices are not out of line with other countries in Europe, although they are much higher than in the United States. If a resilient system is to be maintained, ongoing investment in the whole system will be needed. As Professor Roberts suggested, it may be that a more honest discussion with the public is needed about what this is going to cost. Fundamentally, when making decisions about how much to invest in resilience, it would seem

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136 Q 156

137 Q 154

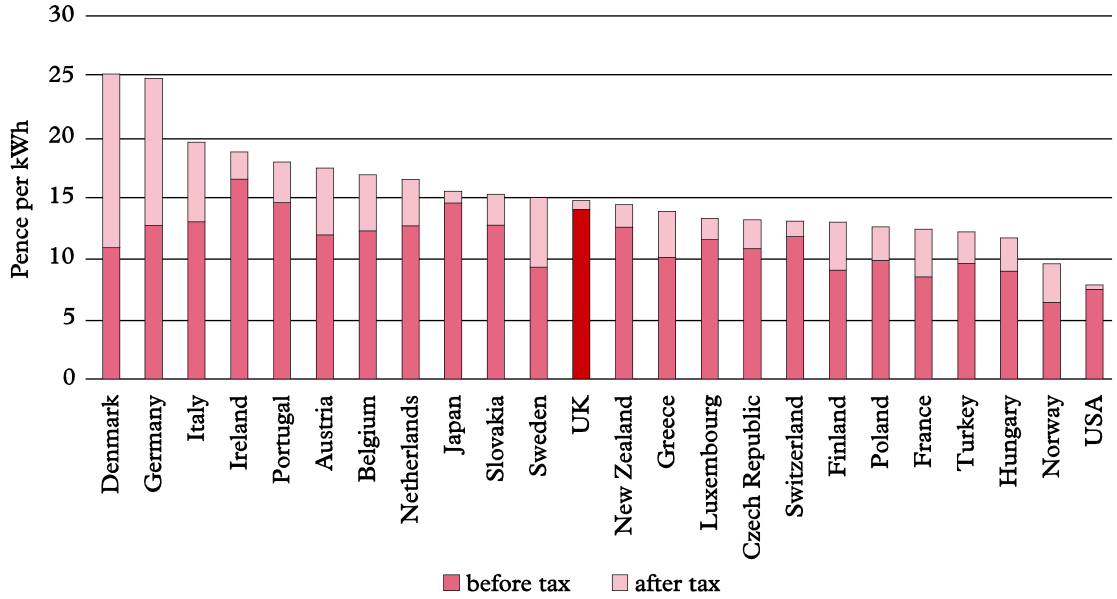
138 DECC, *Estimated impacts of energy and climate change policies on energy prices and bills.* (November 2014): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/371637/prices_and_bills_report_2014.pdf [accessed February 2015]

139 European Commission, Eurostat, *Electricity Prices—Price Systems* (2013): http://ec.europa.eu/eurostat/documents/38154/43500/Electricity_prices_Price_systems_2012.pdf/692ab75f-c69a-4574-9eae-84469504bc8c [accessed February 2015]

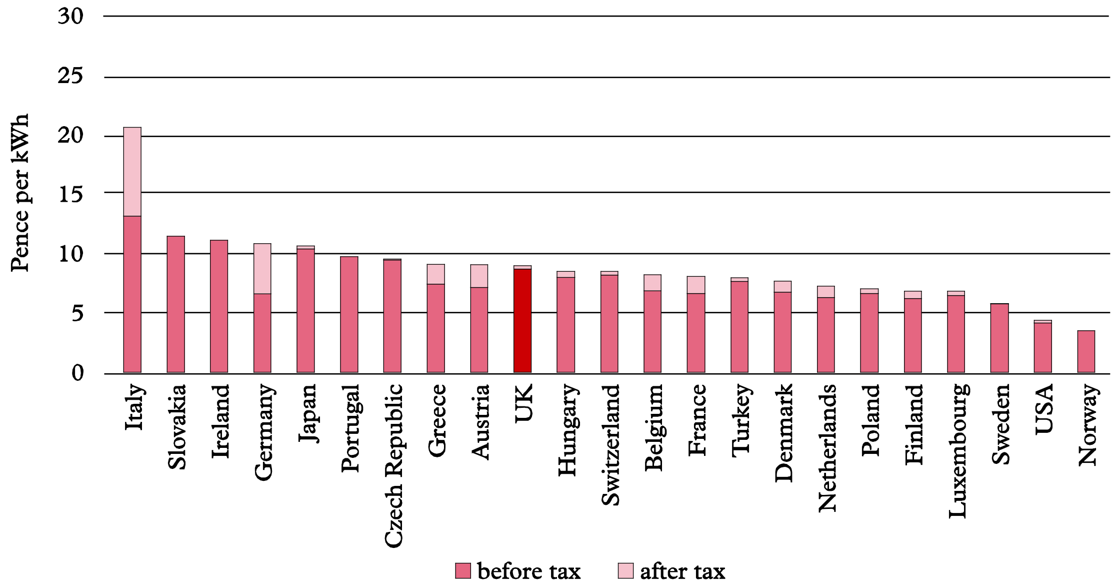
140 DECC, *Supplementary Tables: Estimated impacts of energy and climate change policies on energy prices and bills.* (November 2014): https://www.gov.uk/government/publications/estimated-impacts-of-energy-and-climate-change-policies-on-energy-prices-and-bills-2014 [accessed February 2015]

prudent to have robust data on the costs of electricity shortages. In future, as the electricity system changes, there will be novel risks to resilience and the balance of costs and benefits is likely to change. The cost of resilience, in light of these future challenges, is discussed further in the following chapter of this report.

Figure 5: Average Annual Electricity Prices



Average Domestic Electricity Prices without and with taxes. The UK compared to the International Energy Agency (IEA) countries. Pence per kWh. Data for 2013. Data is not available for Australia, Canada and Spain. Excluding tax data is not available for Korea. The 'excluding tax' price for the USA was estimated using a weighted average of general sales taxes and fuel taxes levied by individual states.



Average Industrial Electricity Prices without and with taxes. The UK compared to the International Energy Agency (IEA) countries. Pence per kWh. Data for 2013. Data is not available for Australia, Canada, Korea, New Zealand and Spain. The 'excluding tax' price for the USA was estimated using a weighted average of general sales taxes and fuel taxes levied by individual states.

Source: DECC, International Energy Price Comparison Statistics *https://www.gov.uk/government/collections/international-energy-price-comparisons* *(accessed December 2014).*

98. **We conclude that successive governments should have anticipated the shrinking capacity margin earlier and taken steps to address it. As a**

result of inaction, the narrow capacity margin which emerged posed a threat to resilience. This has been mitigated using expensive measures with a heavy reliance on fossil fuel generation. This is not a good example of how the trilemma can be most effectively balanced. We recommend that the Government takes a more rigorous approach to long-term planning to avoid such situations arising in the future. Furthermore, we recommend that the Government reassesses whether it is procuring the right amount of capacity through the Capacity Market to offer an optimal cost-benefit balance to consumers.

99. **In order to make effective decisions on resilience, reliable information about the true costs of electricity shortfalls is needed. We are surprised to find a paucity of information in this area. We recommend that the Government funds further research into the costs of shortfalls and publishes its findings. This information should be used to determine whether the current Reliability Standard is appropriate for making decisions on the procurement of capacity.**

100. **We recommend that the Government reviews the contribution interconnection and industrial backup generation could make to capacity margins. It is not currently clear how much industrial backup generation is potentially available. We recommend that the Government identifies and publishes information on the amount of industrial backup generation which could be made available.**

CHAPTER 4: RISKS TO RESILIENCE

101. This chapter sets out current threats to the resilience of the electricity system: technical failure, extreme weather, terrorism ('conventional' and cyber-attack) and space weather.[141] These threats to resilience will, of course, be ongoing and, as such, we also consider how some of these threats might evolve as the electricity system undergoes what is expected to be profound change. It is important to be aware of the scope and character of the different threats to the electricity system. Threats can potentially emanate from a host of sources and while "risks can be mitigated … it is impossible to avoid [them] entirely."[142]

Technical failure

102. Technical failure can lead to power station outages. Recently, there have been several unexpected closures, which resulted from fires at the Ferrybridge, Ironbridge and Didcot B power stations, and the precautionary shutdown of four nuclear reactors at Hartlepool and Heysham.[143] The Government told us that while this cluster of events was "unusual" there was no reason to believe that the situation amounted to anything more than "a simple conjunction of events."[144] Although such unexpected outages increase uncertainty over the volume of plant that may be available in the market, National Grid takes into account the possibility that such events might occur in their planning, and can respond by procuring additional capacity:

> "Didcot, the fire at Ferrybridge and the concerns around the availability of the nuclear stations at Heysham and Hartlepool, are all factors that we took into account that ultimately led to us buying the supplementary balancing reserve."[145]

103. Debates around the resilience of the electricity system are often discussed in the context of whether there is enough generation capacity. When resilience is threatened, however, it is more likely to be a problem at the distribution network level rather than because of generation or transmission faults.

Extreme weather

104. Extreme weather conditions are a common cause of disruptions to power supplies at the distribution network level as such networks "are more prone to wind-blown material, falling trees and other weather impacts."[146] In addition, at the distribution level, "the level of resilience provided against unplanned outages is lower due to the very large number of circuit km and their cost, and the lower impact of an outage."[147]

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141 There are also threats to security of supply posed by geopolitical events, but this was not the focus of our inquiry and very little evidence was consequently received about it.

142 Written evidence from the Government (REI0040)

143 Written evidence from EDF Energy (REI0030)

144 Q 18 (Sarah Rhodes)

145 Q 60 (Mike Calviou)

146 Written evidence from the Energy Networks Association (REI0041)

147 Written evidence from the UK Energy Research Centre (REI0031)

105. The Energy Networks Association told us that the resilience of the distribution network has been improving:

> "In the distribution network, the chance of a customer experiencing an interruption (that is, how often the lights go out) to their electricity supply reduced by 17% between 2002–03 to 2010–11. Over the same period, the time that the average customer is without power (in other words, how long the lights are out) has fallen by 25%."[148]

106. Distribution network operators have been taking steps to increase resilience to extreme weather events:

> "… including flood mitigation, use of insulated overhead line conductors, rebuilding lines to a heavier construction specification, increasing lightning surge withstand capability, and automated switching to isolate faults and restore supplies. Resilience could be further improved by even greater levels of investment (with resulting increases in consumer prices which Ofgem's consumer surveys have indicated would not be supported)."[149]

107. While improvements to distribution network level resilience are to be welcomed, it is inevitable that incidents of communities experiencing power outages due to extreme weather conditions will continue to occur, as they have done this winter. The principal challenges are: to make the distribution network as resilient as possible, in light of the costs that consumers will support; ensure that resources are adequate to restore power supplies as soon as possible; and, in the interim, make sure that measures are in place to communicate with those affected.

108. Christmas 2013–14 saw particularly severe storms which resulted in 750,000 households being affected by power disruptions.[150] A criticism following these storms was the lack of effective communication with affected consumers. We note that measures to improve communication are now being taken, principally by putting in place a single national emergency number, which consumers can call in the event of a power outage. This is intended to make it easier for consumers to get up to date information during a power outage, without needing to know which specific Distribution Network Operator they need to contact. It will, however, be some time until this number is available, with roll out expected in April 2016—if the project progresses as planned.

109. **In the event of power outages, it is essential that those consumers affected can access accurate and timely information about the developing situation. We note and commend the work underway to improve communications, including the provision by April 2016 of a single national emergency number for consumers to use to contact their Distribution Network Operator in the event of a power disruption. It is important that this deadline is met and that a comprehensive plan is developed for dissemination of the national**

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148 Written evidence from the Energy Networks Association (REI0041)

149 Written evidence from the Institution of Engineering and Technology (IET) (REI0032)

150 Written evidence from the Government (REI0040)

emergency number, and Parliament will wish to be kept appraised regularly of progress.

110. The threat from extreme weather events is predicted to increase due to the effects of climate change, though there is considerable uncertainty surrounding the projections. The Resilient Electricity Networks for Great Britain[151] (RESNET) project told us that:

> "… it is becoming increasingly apparent how the critical electricity infrastructure must also be resilient to high-impact low-probability events, such as extremes of weather. In the light of climate change, this is increasingly important as the frequency, intensity and duration of extreme weather events is expected to increase in the future …
>
> … the considerable uncertainty associated with projections of future extreme wind speeds (and in general extremes of weather) leaves serious uncertainty in the estimation of the extent of these measures required to meet possible increased hazard. Whilst it is very unlikely that the future wind and icing regimes in the UK will be as hazardous as those in other parts of the world (such as North America or Scandinavia), there are plausible suggestions that the frequency of occurrence of wind speeds capable of disrupting distribution networks may increase, as has been observed in recent years (e.g. winter of 2013/2014)."[152]

111. We note that, within the RESNET project, a time-series simulation-based tool has been developed and applied on a test network for assessing the resilience of the transmission system to extreme wind conditions. This tool is being applied to a model of the UK's transmission network, which will both yield information on the level of resilience of the system to severe weather conditions and quantify the effects of resilience enhancement provisions. This research is important and we look forward to its outputs. Moreover, it is to be hoped that further research into the effects of extreme weather conditions on the network will receive appropriate funding in the future.

Terrorism: physical and cyber

112. The threats posed to critical national infrastructure from terrorism, both 'conventional' and cyber, are significant, and in respect of the latter, it is clear that this relatively novel threat will be a key preoccupation in the coming decades.

113. The Institution of Engineering and Technology (IET) told us that it was reliance on Information and Communications Technologies (ICTs) in the electricity system which presented vulnerability:

> "Many aspects of the UK's electricity system depend on computer-based systems. It has been reported that foreign states and others have been

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151 The RESNET project is constituted of five discrete work packages, ranging from electricity demand and supply scenarios to a systematic resilience analysis of the UK power network, evaluation of adaptation measures, and social responses to these measures. The project is funded by the Engineering and Physical Sciences Research Council (EPSRC) and is a consortium of universities and research centres (University of Manchester, Tyndall Centre and Newcastle University), supported by stakeholder partners (National Grid, the Environment Agency and Ove Arup).

152 Written evidence from the Resilient Electricity Networks for Great Britain (RESNET) Project (REI0025)

> detected probing for vulnerabilities in critical infrastructure, so it must be assumed that the UK is also a potential target."[153]

114. Professor Fisk and Dr Chana, Imperial College London, claimed that: "Energy companies have now become a prominent target. One recent piece of vicious malware is even being called 'Energetic Bear'."[154]

115. The Government and the industry have been—and are—working together to put in place measures to counter cyber threats. The Government told us that:

> "… cyber security is [also] playing an increasingly prominent role in the Department's work and we are working with other government departments and agencies, as well as with industry partners, to ensure that the risks to the energy sector are understood and that appropriate mitigations are established."[155]

> "There is a lot of work going on with the industry, with DECC, with the security agencies to analyse the cyber systems, to define what is critical national infrastructure and to establish the degree of vulnerability protection to this threat. It is not a new threat, but it is a fairly recent one. The industry does not start from a position of being unprotected—quite the opposite. The industry is probably ahead of the game relatively. But what we are doing is ensuring that there are audits done by the security services of the resilience of each critical piece and it is like the layers of an onion—you start with the centre and you work your way out. A lot of mapping is going on as to how the system operates, where all the links are and a lot of work is going on, both with individual companies and collectively, to establish things like minimum standards but also to make sure that each individual business is resilient, so there is a lot happening."[156]

116. The Secretary of State for Energy and Climate Change, Rt Hon Ed Davey MP, was unequivocal about the Government's focus on cyber security. He noted, however, that the threat was evolving and required constant vigilance:

> "From the Cabinet Office to No. 10, across government, there is a major effort to look at cyber issues. We have seen investment in the key transmission and distribution mechanisms, but because it is an evolving threat and one that we take very seriously, we do not think that we have reached a final solution for dealing with cyber and we keep it under constant review."[157]

117. Threats to cyber security are evolving as the electricity system becomes more complex and more dependent on ICT (and ICT is, of course, dependent on electricity). The Energy Networks Association highlighted the scale of the vulnerabilities that will accompany increased use of ICT:

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153 Written evidence from the Institution of Engineering and Technology (IET) (REI0032)

154 Written evidence from Dr Deeph Chana and Professor David Fisk (REI0051)

155 Written evidence from the Government (REI0040)

156 Q 18 (Sarah Rhodes)

157 Q 190 (the Rt Hon Ed Davey MP)

> "Increasing use of communications technology and data in the development of a smart grid will be vital to managing shifting patterns of supply and demand in the future energy system. However, it will create new vulnerabilities, with thousands of potential access points providing opportunities for cyber criminals."[158]

118. The Institution of Engineering and Technology (IET) told us that increased dependence on automation would have consequences for cyber security:

> "… the future system will be much more dynamic and reliant on fast communication and data analysis to ensure technical security and stability. This will reduce the feasibility of manual operation and increase dependence on automation, further exacerbating the potential consequences of cyber-attack."[159]

119. As noted above, the Government and industry are active in assessing and mitigating the risks to cyber security. There are some concerns, however, that, particularly on the demand side, not all issues are being addressed. Dr Deeph Chana and Professor David Fisk, Imperial College London, argued that:

> "There are also significant issues on the demand side. Work between the Laing O'Rourke Systems Centre and Imperial's Institute for Security Science and Technology has exposed the vulnerability of 'demand side' SCADA systems. These are often running on legacy, unsupported, software platforms, whose errors in configuration can be uncovered by anyone using a web searcher. They are the very type of system that would be expected to take part in automated demand response programmes."[160]

120. The IET expressed concern that smart metering security architecture was sub-optimal: "the design and implementation of the Smart Metering security architecture has not followed best practice for cybersecurity. The costs and benefits of best practice cybersecurity have not been addressed in detail in any DECC documents that the IET has reviewed."[161] Others, however, considered that the cyber security issues associated with smart meters have been taken into account. Dr Porter, Chief Executive Officer, BEAMA,[162] said that the risk was very low.

> "An office of GCHQ has been involved in working with DECC to work out exactly the security requirements that have to go in all the equipment. From the individual smart metering side, it is felt there is a very low risk. There may be some risk that somebody could hack into your smart meter, but you have to ask why.
>
> In terms of the overall cybersecurity, on whether you could shut the country down, the feeling from those experts is that is not the case. If you have a wider smart grid and you have the whole system to be smart, that is a much greater level of risk and there will be even more requirement to get it right. In terms of the smart meter rollout, everyone believes,

158 Written evidence from the Energy Networks Association (ENA) (REI0041)

159 Written evidence from the Institution of Engineering and Technology (IET) (REI0032)

160 Written evidence from Dr Deeph Chana and Professor David Fisk (REI0051)

161 Written evidence from the Institution of Engineering and Technology (IET) (REI0032)

162 BEAMA is the trade association for the electrical manufacturing industry.

including the security experts, that there is sufficient security put in place for the individual householder or, indeed, building and it does not cause a threat for the whole country."[163]

121. In tackling the issue of cyber security, we agree with Dr Deeph Chana and Professor David Fisk, Imperial College London, who told us that "cyber security considerations have to be built in from the start and not applied as a late add-on."[164] Such planning must be paramount.

122. **The risk of breaches to cyber security are real and will continue to evolve as the electricity system becomes ever more dependent on ICT. While we note that the Government is taking action in this area, we are concerned about the threat in the medium term as the electricity system becomes increasingly reliant on fast communication, on data, and dependent on automation. As new threats are identified so the Government must work ever more closely with stakeholders and provide appropriate funding for efforts to combat cyber-attack. The Government must ensure that cyber security factors are embedded at the earliest stages of electricity system design.**

123. Regarding the threat from 'conventional' terrorism, we note that the electricity system is critical national infrastructure and it must be assumed that it is a potential target. It is worth recalling the IRA's planned attack in 1996 on electricity substations, which aimed to cut off London's electricity supply.

The risk register and emergency response

124. Identifying threats at as early a stage as possible and emergency planning are critical activities for the Government. The Government explained to us how it plans for emergencies:

> "The cross sector National Risk Assessment (NRA) is updated bi-annually (from 2014, previously annually) and provides a SECRET, strategic assessment of the most significant emergencies that could affect the UK over the next 5 years. A declassified version, the National Risk Register is published by the Cabinet Office. These assessments underpin energy sector resilience planning and are used to inform the energy sector resilience plan, which provides assurance to ministers that mitigations and programmes are in place, and reports on the progress of delivery. As of May 2014 DECC owns 15 risks within the NRA 2013."[165]

125. The Energy Emergencies Executive Electricity Task Group (E3C ETG) also plays a key role in emergency planning. This group provides a forum for cross sector collaboration:

> "[E3C ETG] brings together representatives of the electricity industry, the regulatory authority(s) and the lead Government department to consider and prepare for events which may impact on the resilience of the

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163 Q 122

164 Written evidence from Dr Deeph Chana and Professor David Fisk (REI0051)

165 Written evidence from the Government (REI0040)

electricity infrastructure … [and] reports into E3C on emergency planning activities related specifically to electricity."[166]

126. A Government official told us of its emergency plans in the event of a shortage of electricity:

"We have a whole set of processes that come into play if there is a shortage. Those processes are there to protect essential users, they are very regularly dusted down and that priority-users list is updated on a very regular basis. Alongside that we also expect key users to have their own business continuity arrangements so that they do not start completely unprotected. But, clearly, in the event of a big system issue then it is very much a question for Government working with the sector to ensure that electricity flows to where it is needed."[167]

127. We were reassured to learn that periodic rehearsals of emergencies are held. The Secretary of State told us that he had been involved in one such rehearsal, and noted that: "there have been more than the one that I was personally involved in, but Ministers tend to be involved at different levels, with junior or Cabinet Ministers in some of these exercises."[168] Jonathan Mills, Director, Electricity Market Reform, DECC, added that:

"A large number of scenarios that might be primarily about testing some element include lots of electricity suppliers as a dimension. Without giving confidential details, electricity is considered a dimension in a large range of scenarios that are tested."[169]

We advocate Ministerial involvement in rehearsals of emergencies. It is valuable for Ministers and officials to have the opportunity to practice decision making processes in a simulated environment.

128. It is, of course, difficult, if not impossible, for us to satisfy ourselves entirely that the Government's assessment of hostile threats and its emergency planning processes are optimal. Rightly, the Government must be careful about the national security material that it puts into the public domain. Scrutinising sensitive matters of national security is—and always has been—problematic for this reason. In order to try and reassure ourselves a little more, we received a private briefing from Government officials as part of our inquiry (see Appendix Five). This was a helpful exercise. Nevertheless, it remains the case that it would be unwise for us to reach a firm view on emergency preparedness as we are not in possession of all the relevant information. The Government has sought to be helpful and as open as they can be, for which we are grateful, but our conclusion must be cautious.

129. **We conclude that, as far as we are in a position to judge, the Government and relevant bodies have taken—and continue to take—steps to ensure resilience to threats, and that planning and emergency response procedures seem robust.**

166 Written evidence from E3C ETG (REI0033)

167 Q 20 (Sarah Rhodes)

168 Q 190 (the Rt Hon Ed Davey MP)

169 Q 190 (Jonathan Mills)

130. **We would urge the Government, however, to ensure that it:**

- **engages actively with the science and engineering community in order to identify new and emerging threats to resilience; and**
- **draws on the very best available evidence to enable timely and cost effective planning.**

131. **In emergency planning, there is no substitute for conducting periodic simulations of emergency scenarios with Ministerial involvement. We therefore recommend that periodic simulations of emergency scenarios with Ministerial involvement continue to take place and that information about such exercises, is, as appropriate, reported to Parliament.**

Space weather

132. Understanding the threats posed by space weather (or solar storms) has become a topic of increasing interest to scientists across the world. The Royal Astronomical Society (RAS) explained space weather to us:

> "When large eruptions of material from the Sun (coronal mass ejections) pass over the Earth they can generate severe geomagnetic storms that inject quasi-DC electric currents (geomagnetically induced currents) into power grids and disrupt the operation of key grid components such as transformers. This disruption can cause parts of the grid to shutdown leading to widespread loss of power for many hours and, in worst cases, damage to a few transformers, which could lead to long power outages in affected areas."[170]

133. The RAS noted that the UK has been at the forefront of work to understand space weather and that National Grid has taken measures to enhance resilience:

> "The UK has been taking an international lead role in these efforts to understand and mitigate this risk. In particular National Grid has been working since the 1990s to improve its resilience against space weather, e.g. through use of more resilient transformers. National Grid also has specific, well-exercised, procedures for operational measures that can provide additional short-term resilience of electrical infrastructure in response to reliable warnings of adverse space weather."[171]

134. Moreover, the RAS reported that the Government is seized of the threat from space weather and that space weather "was formally recognised as a significant risk to the UK by the incorporation of severe space weather in our [the UK's] National Risk Register in 2012."[172] We welcome ongoing efforts to understand and mitigate the threats from space weather and endorse the Royal

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[170] Written evidence from the Royal Astronomical Society (REI0048)

[171] *Ibid.*

[172] *Ibid.*

Astronomical Society's view that research into space weather should receive appropriate funding. [173]

[173] We also note the recent publication of a report, based on contributions from the public, scientific and government experts, and from a series of public dialogue events, which offers recommendations on actions to deal with the impact of space weather events in the future. Sciencewise, the Science and Technology Facilities Council RAL Space team, the Natural Environment Research Council (NERC), National Grid and Lloyd's of London, *Space Weather: Public Dialogue* (February 2015): http://www.stfc.ac.uk/RALSpace/resources/PDF/SWPDFinalReportWEB.pdf

CHAPTER 5: CHANGING DEMAND

135. This chapter, and those that immediately follow (Chapters 6 to 8), consider challenges to the resilience of the electricity system in the medium term—to 2030—as the electricity system embarks on a period of change, which experts expect to be at least significant, if not profound. For its part, the Government told us that:

> "In the medium to long term the UK's energy system also faces a great deal of change as existing infrastructure closes, domestic fossil fuel reserves decline and the system adapts to new technology, including a more decentralised and intermittent supply as an inevitable consequence of a higher mix of renewables."[174]

136. As noted in the previous chapter, some existing threats to resilience may increase in the coming years. It is worth noting, however, that some threats are predicted to reduce. For example, the threat from geopolitical factors, though beyond the scope of this inquiry, would be expected to decrease as electricity generation is decarbonised and the dependence on fossil fuel energy sources decreases.

137. At present, with 63.5% of the UK's electricity generation coming from fossil fuels, the cost of electricity is heavily influenced by fluctuations in fossil fuel prices. Indeed, during the course of this inquiry there have been sharp falls in the price of oil and gas. Retailers are beginning to respond by cutting prices, to the benefit of consumers. Future fossil fuel prices are expected to remain volatile and influenced by many factors. Although it might be expected that the current fall in fossil fuel prices would make renewables less competitive, there is debate about how the market will respond.[175]

138. Generating electricity from renewables requires costly infrastructure, but once installed, the energy sources (for example sun, wind or wave) come at zero cost. This raises the possibility that, in future, prices and supply will be more stable. Other geopolitical risks may emerge, however, due to the use of rare minerals for renewables and batteries.

139. One factor which is unlikely to affect resilience is a shortage of fossil fuels. As Professor Dieter Helm from the University of Oxford told us:

> "The one medium-term 'risk' that I would pay much less attention to—but clearly the Government thinks they should pay much more attention to—is whether or not we will get enough supplies of fossil fuels. We have enough fossil fuels in the world to fry the planet many times over. If only we had to worry about security of supply on fossil fuels, maybe we might do something about climate change, but that is not one of our problems."[176]

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[174] Written evidence from the Government (REI0040)

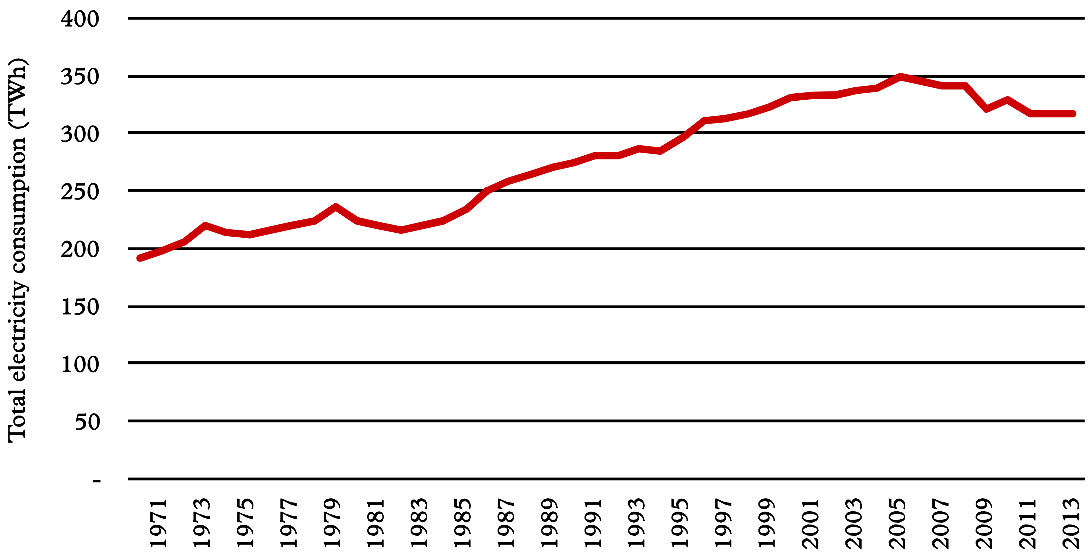
[175] BBC News Online, '*Will the falling oil price undermine green energy?*' (30 January 2015) http://www.bbc.co.uk/news/science-environment-31057078 [accessed February 2015]; 'Let There Be Light', *The Economist* (17 January 2015): http://www.economist.com/news/special-report/21639014-thanks-better-technology-and-improved-efficiency-energy-becoming-cleaner-and-more [accessed February 2015]

[176] Q 45

140. It is important to stress at the outset, as we look towards 2030, that the uncertainties cannot be overestimated. As the Secretary of State, Rt Hon Ed Davey MP, put it: "the thing I am certain of is uncertainty."[177] It is therefore vital that a flexible approach is maintained: "If you have too hard-and-fast plans for what the system needs to look like in 2030, you will almost certainly get it wrong, because the changes are quite profound and have quite large degrees of uncertainty."[178]

141. There is significant uncertainty about the levels of future demand for electricity. Although demand has been falling in recent years, as shown in Figure 6, this may be reversed as the economy recovers. Looking towards 2030, a range of factors will be at play—including possible improvements to energy efficiency, changing behaviours and social norms, electrification of heat and transport and increasing use of air conditioning—all of which make predicting future demand with any certainty problematical. Although levels of future demand are difficult to predict, as explained below, the Government's expectation is that in the future demand for electricity will be greater than it is today.

Figure 6: Total Electricity Consumption



Source: DECC, Historical electricity data 1920–2013—Electricity supply, availability and consumption *https://www.gov.uk/government/statistical-data-sets/historical-electricity-data-1920-to-2011* *[accessed February 2015]*

Data for all generating companies are only available from 1986 onwards. Before 1986 the data are for major power producers, transport undertakings, and industrial hydro and nuclear stations only.

142. The Dynamics of Energy Mobility and Demand (DEMAND) Centre, one of six research centres funded by the Research Councils, examining end-use energy demand from different perspectives, told us that it would be misguided to assume that future demand will mirror current demand:

> "We should not assume that future demand will look like current demand. Current government policies rely on scenarios and analyses of options for promoting efficiency and decarbonising energy supply whilst maintaining current standards of living. In effect these methods presuppose that

177 Q 195

178 *Ibid.*

present practices involving energy use will remain the same far into the future. This is highly unlikely: ways of living change all the time, both potentially leading to escalations and reductions in future energy use."[179]

Electric vehicles and heat pumps

143. Electric vehicles and electric heat pumps are two technologies that are expected to increase demand for electricity.

Box 4: Electric Vehicles

An electric vehicle is one that is propelled by electric motors (i.e. using electrical energy). If electric vehicles are widely taken up then they will increase electricity demand[180], though this could be concentrated during off peak hours. On the other hand, a smart grid could allow battery-powered electric vehicles to supply power to the grid, e.g. during peak times when prices are high, and then to recharge during off peak hours. They could also further contribute to electricity security by providing a backup supply during power outages. Electric vehicles are not the only low carbon option for road transport—hydrogen and biofuels (2nd or 3rd generation) also offer potential.

Box 5: Heat Pumps

Heat pumps capture heat from sources such as the air or the ground and increase its temperature using electricity. Possible applications include space and water heating, cooking and industrial processes. Using heat pumps as opposed to gas could significantly reduce heating-related CO_2 emissions. A widespread uptake of heat pumps would increase the demand on the electricity grid, requiring greater generation and network capacity. Most importantly, the demand at peak times could increase significantly. If heat pumps are to be effective in households, however, it will be important that homes are insulated to an adequate standard.

144. The Government told us that: "electricity demand is expected to continue to grow over the coming decades as we increasingly turn to electricity for heat and transport."[181] The UK Energy Research Centre (UKERC) echoed this assertion and argued that electrification of large parts of the energy used for heating or transport "would change its time-of-use profile, placing ever increasing pressures on the electricity system."[182] Charging electric vehicles will bring complexity and it will be important that vehicle charging management systems and standards are carefully designed, as the Energy Technologies Institute (ETI) explained:

"Vehicle charging is a manageable problem, since the overnight load can be fitted into the available system capacity. However simplistic charging management solutions will create unfortunate effects, such as cliffs of coordinated switch-on and switch-off. There are other issues that need to be addressed in designing an effective charging system. Unmanaged

179 Written evidence from the DEMAND Centre (REI0037)

180 Dr Harrison from the IET told us that: "the average demand of a house at the moment is about 1.5 kilowatts, while an electric vehicle charging load is about 7.5 kilowatts." (Q 8)

181 Written evidence from the Government (REI0040)

182 Written evidence from the UK Energy Research Centre (UKERC) (REI0031)

systems will contribute significantly to peak load, since people naturally plug in at the point of arrival home and then charge through the evening peak. It is therefore critical that carefully designed vehicle charging management systems and standards at the national level are developed and incorporated into any large scale demonstrations and early roll-outs. These systems need to address both the capacity of the national system and also the local distribution system."[183]

145. Equally, the ETI argued that electric heating will present management challenges:

"Electric heating is not an inherently manageable problem, since it is inevitable that everyone in an area will require heat on cold days and there is a real risk of distribution systems overload. Air source heat pumps have their lowest performance when it is cold and it is not economic to size them to cope with infrequent peak loads and they therefore usually include additional power through resistive heating, further reducing performance at peak demand. Depending on the detail of the local built environment, pumping heat out of the air around buildings and reducing building heat loss rates could further reduce heat pump efficiency."[184]

146. Michael Ware, Partner for New Energy and Environment, BDO LLP, expressed concern that the Government was not reconciling capacity constraints with promoting policies that will increase demand, such as electric vehicles and heat pumps:

"We have a Government that is faced with capacity constraints across the grid and yet other parts of DECC are cheerfully promoting policies that will increase demand upon the grid—in particular, I mean electric cars and heat pumps. We spend quite a lot of time thinking about electric cars but, to our mind, there seems to be no end-point as to what percentage of the UK fleet the Government is trying to persuade to shift to electric and, secondly, what the impact upon the grid will be of shifting that percentage across. Through our conversations with DECC we have never found the person who knows the answer to those two questions and I suspect they do not exist."[185]

Air conditioning

147. Another technology which will affect electricity demand is air conditioning. Professor Walker, Co-Director of the DEMAND Centre, told us that the UK is seeing increasing use of air conditioning:

"Air conditioning is increasingly moving into not just office environments but a lot of other non-domestic settings, and there is a big concern that air conditioning could be moving into the domestic world as well. That is an entirely new form of energy consumption that we do not necessarily need at all because there are many ways of achieving cooling without air conditioning. It is one of the social dynamics that we are interested in investigating and trying to understand. Why is air conditioning moving

183 Written evidence from the Energy Technologies Institute (ETI) (REI0018)

184 *Ibid.*

185 Q 118 (Michael Ware)

through the UK building stock in the way it is, introducing new demands for electricity on the system?"[186]

148. We heard that climate change may result in higher demand for air conditioning: "In the medium term, climate change is likely to increase the air conditioning load; cooling is responsible for 4 per cent of the total UK electricity demand and in London alone demand for cooling is expected to double by 2030, to nearly 3 TWh per year."[187] [188]

Energy efficiency and reducing energy use

149. Against this background of increasing demand for electricity, improving energy efficiency and reducing energy use will be important. Ofgem told us that: "Promoting energy efficiency is fundamental as it achieves all three objectives [of the energy trilemma] at once."[189] The Institution of Engineering and Technology argued that enhanced energy efficiency or behavioural changes might to some extent be able to offset increases in demand:

> "… the possibility of massive increases in electricity demand in the event that most transport and space heating becomes electrified … could be offset to some degree if real progress is made on policies to improve energy efficiency, and change consumer behaviour to either use less energy, or shift more of their energy consumption to times when the system is less stressed."[190]

150. We heard about the importance of building regulations in improving the energy efficiency of buildings. This will be particularly important if there is a shift to heating using heat pumps. Retrofitting existing buildings will be at least as important, if not more, as ensuring high standards for new builds. Efficiency improvements could significantly reduce the amount of electricity needed and, crucially, reduce demand for electricity, which would otherwise result from the widespread electrification of heat. These effects would probably only be fully felt after 2030, but would start to be important before then if heat pumps are taken up in significant numbers. Professor Richard Green, Professor of Sustainable Energy Business, Imperial College London, explained how building regulations could be used to enhance energy efficiency:

> "We are not making nearly enough use of energy efficiency. The builders will tell you, 'If we have to make our house more efficient the price to the customers will go up'. Some fairly basic economics would tell you the price that people are willing to pay for their houses and are able to pay for their houses will stay the same. If the cost of building the house goes up a bit, and it probably would, the value of the land underneath it goes down, which is what the builders hate, but the value of the land without permission to build a shoddy house is very low. If a local council gives a builder permission to build a shoddy house, the builder makes a lot of money or the landowner makes a lot of money. If you give them

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186 Q 119 (Professor Gordon Walker)

187 Written evidence from the UK Energy Research Centre (UKERC) (REI0031)

188 It is worth noting that the effects of climate change might mean, conversely, that less heating is required in winter.

189 Written evidence from Ofgem (REI0044)

190 Written evidence from the Institution of Engineering and Technology (IET) (REI0032)

permission to build a decent house, they will still make quite a bit of money but just not quite as much."[191]

151. **While it has not been a principal focus of our inquiry, we conclude that improving energy efficiency is of vital importance. For example, if heat pumps are to be effective, then having well insulated buildings will be critical. Effective retrofits, for instance, will reduce the amount of electricity needed for heat pumps, and will arguably help to reduce the stress on the electricity system in the future. It is essential for building regulations to ensure energy efficiency.**

152. Government policies may not be effectively promoting either increased energy efficiency, or demand reduction. The UK Energy Research Centre told us that Electricity Market Reform (EMR) "has not been designed adequately to incentivise electricity demand reduction."[192] Professor Walker, Co-Director, the DEMAND Centre, argued that the Government was not sufficiently ambitious and more attention needed to be put on reducing demand:

> "I would also question whether the Government is sufficiently ambitious in its overall objectives because, if you take the 2050 carbon scenario seriously and the targets seriously, we are talking about major reductions in energy demand overall—not just the time of use but the overall energy demand reduction.
>
> There has been a lot of debate in Europe recently about whether there should be a mandatory Europe-wide energy reduction target and proposals came from the Parliament for a 40% reduction in overall demand by 2030. Unfortunately, from my point of view, our Government was instrumental in blocking that and the outcome has been a 27% reduction—we are not quite sure why exactly 27%—by 2030 but not on a mandatory basis. I think overall there is a lack of ambition and a lack of realism about how much you need to bring down energy demand, particularly if you are electrifying heating and vehicles. You cannot be doing that at the same as allowing energy demand to stay pretty much where it is or to allow it to increase overall."[193]

Social futures

153. In order to understand future energy demand, it is important to try to understand people's behavioural patterns. The DEMAND Centre told us that its research showed that demand depended on shared social practices, not individually chosen behaviours:

> "To the extent that energy demand is included within energy policy, it tends to be considered either in terms of technical efficiency or the behaviour of individuals—with the implication that such behaviour can be changed through incentives or education. However, the research of the DEMAND Centre shows that energy demand predominantly depends not on individually chosen behaviours, but on the shared social practices

191 Q 85 (Professor Richard Green)

192 Written evidence from the UK Energy Research Centre (REI0031)

193 Q 118 (Professor Gordon Walker)

that make up accepted normal and everyday patterns of living, working and moving around."[194]

154. Professor Walker, Co-Director of the DEMAND Centre, stressed the importance of trying to model social processes and argued that more onus needed to be placed on this:

> "We have started to talk to DECC and Ofgem about how good their scenario work is, particularly in thinking about social futures. They are very good at dealing with the variables they feel comfortable with, like technological efficiencies and different scenarios for making technologies more efficient or with population growth or economic growth—the big macro questions. However, if we went into, 'Well, what is the future of lighting at home? What is the future of cooking? What is the future of all sorts of different ways in which energy is used', their scenarios get very basic, if they deal with any of those questions at all. They had a review done recently of all their energy system models, which concluded that there was very little effort going into the modelling of social processes. We think there would be ways of going into those.[195]

Distribution networks

155. We were told that there is a need for the distribution network to be prepared for the challenges ahead. The Government asserted that the role of Distribution Network Operators might need to evolve:

> "With the projected increase in electrification of transport and heating and increasing distributed generation Distribution Network Operators (DNOs) may need to adapt and become more like DSOs where they can act as local system operators increasingly balancing demand within their local network."[196]

156. Dr Harrison, Chair of the Energy Policy Panel, Institution of Engineering and Technology, stressed the importance of understanding how increased demand would affect the network:

> "… if you do start doing interesting things with consumer demand, you need to start worrying about the impact on distribution networks, for example, voltage control and such like. It is all linked in also with things like solar PV panels on people's roofs and what that does. If we move to a world of electric vehicles or heat pumps, they have massive implications for demand levels. So the average demand of a house at the moment is about 1.5 kilowatts, while an electric vehicle charging load is about 7.5 kilowatts. So you have really major implications if you move to that, including for distribution systems. You start to get to a place where you need to understand both the impact on supply-demand balance of managing demand and the impact on the network."[197]

194 Written evidence from the DEMAND Centre (REI0037)

195 Q 120 (Professor Gordon Walker)

196 Written evidence from the Government (REI0040)

197 Q 8

Demand side response

157. Demand side response (DSR) describes the process of electricity users adjusting the amount of electricity they use at certain times in response to incentives. To maintain electricity supply, the supply and demand of electricity must be flexible enough to enable them to match each other. Such flexibility has commonly been provided by the supply-side, by switching generating capacity on or off. DSR is about enabling consumers to provide flexibility in the system. For instance, the advent of smart meters will offer consumers a range of intelligent functions. We heard that while DSR has significant potential, current policies do not set it on an equal footing with generation and more could be done to harness its potential.

158. Ofgem asserted that DSR has credible potential and could contribute both to reducing system stress and sustainability goals:

> "DSR could play an increasingly important role in supporting the improvement of the resilience of the UK electricity system until 2020 and beyond. This is because DSR has the potential to reduce demand at times of system stress; for example during peak winter periods or when unexpected events happen, such as the sudden loss of generation. DSR could also contribute to our sustainability goals by reducing the need for new investment in generation and network capacity provided this is properly balanced against overall security of supply requirements."[198]

159. BDO LLP, an accountancy and business advisory firm, argued that DSR could play a far larger role in reducing peaks in demand and obviate the need for expensive new generating capacity:

> "… electricity demand in the UK varies hugely during the course of the day with the greatest peaks usually between 4pm and 7pm on winter evenings. We believe that demand-side response could play a much larger role in reducing these peaks, both by calling on unused generating capacity and by incentivising end users to reduce demand at these times. By developing policies that minimise the impact of these peaks, the Government can partially reduce the need for expensive new capacity."[199]

160. In order to make effective use of DSR it is important that demand is well characterised and understood. We note the large body of work undertaken in the GB Electricity Demand project run by Sustainability First, which has made an important contribution to the understanding of the nature of demand and the potential for industrial and domestic DSR.[200] During this inquiry, we heard, however, that gaps remain in the evidence available on the current uses of electricity, which will make it difficult to make greater use of DSR, particularly at the domestic level. Load shifting, the shifting of energy usage from one period of time to another, is subject to important social as well as technical and economic constraints:

198 Written evidence from Ofgem (REI0044)

199 Written evidence from BDO LLP (REI0011)

200 Sustainability First, 'GB Electricity Demand Project': http://www.sustainabilityfirst.org.uk/gbelec.html [accessed February 2015]

> "… there is a major gap in the evidence base on the demand side, with very little knowledge about why electricity is used at different times, including during peak periods."[201]

161. Professor Walker elaborated on the deficiency of the evidence base and argued that it was unclear as to how much demand was flexible:

> "The big question is: what can realistically be moved out of that time period? What is flexible in that evening peak? We have been doing work on this looking at time-use diary data, looking at how people are using their time. What is going on within the peak period? How is that locked into other things that people are doing like working hours and school hours? … The question about what is flexible and what is not flexible in this is important and it is not sufficiently understood as yet. We are starting to get some indication from some of the early trials with smart meters and various things, but I think there is a real lack of detailed understanding about how electricity is being used at all and, therefore, if we do not know that then we do not necessarily know how much of that is moveable."[202]

Industrial DSR

162. National Grid already uses DSR as a balancing tool through services such as its Short Term Operating Reserve (STOR).[203] Currently it is mostly large industrial users who benefit. Users enter into contracts offering cheaper electricity prices in exchange for a commitment to reduce demand on request to help balance the system when capacity margins are tight. Box 6 provides examples of how DSR is currently used. The Government explained that DSR has been used for at least 60 years:

> "DSR in the UK electricity network is not new, and has been used in the UK Electricity Network for at least the last 60 years to balance available generation with demand. However, in the past, providing DSR has been more suited to large industrial consumers of electricity, e.g. such as in smelting of aluminium, where the manufacturer offers to suspend production at times of network stress in return for lower electricity prices."[204]

Box 6: Existing Demand Side Response—Case Studies

Demand Side Response is already used as a balancing tool. Companies which already participate in DSR cite the benefits as including: reduced energy costs and a reduced carbon footprint.[205] J Marr Group, which operates a cold store and logistics business, participates in DSR through the aggregator Energy Services Partnership.[206] J Marr Group estimates that its

201 Written evidence from the DEMAND Centre (REI0037)

202 Q 120 (Professor Gordon Walker)

203 National Grid, 'What Are Reserve Services?: http://www2.nationalgrid.com/UK/Services/Balancing-services/Reserve-services/ [accessed February 2015]

204 Written evidence from the Government (REI0040)

205 Written evidence from Flexitricity (REI0058); Written evidence from KiWi Power (REI0057)

206 Part of Ameresco Inc.

involvement in a range of DSR initiatives has yielded benefits of £240k since 2012:

> "J Marr Group interests include a growing cold store and logistics business and being Europe's largest supplier of ice products. One of the company's main sites is based in Northern Powergrid's Yorkshire region, where they consume over 15 GWh of electricity per annum. The site has been involved in demand response initiatives since 2007, including winter peak cost avoidance and the provision of services to National Grid. This flexibility is achieved primarily by managing cold store temperatures and procedures, so that the thermal inertia in the building can maintain appropriate operating conditions. The site also tailors shift and production patterns in response to longer term signals from electricity charges."[207]

Norish, a cold storage and logistics operator, has a similar arrangement in place with the aggregator Flexitricity:

> "Norish operates eight storage and distribution centres across England and Wales, including more than 75,000 racked pallet spaces, of which 60,000 are temperature-controlled. The company retains food and related products for its customers at temperatures as low as–29°C. They have four sites connected to Flexitricity's smart grid and have been earning revenue from Flexitricity's services since 2008. At times of high national electricity demand, or if a major power station fails, Flexitricity turns down Norish's cooling plant for short periods to reduce the stress on the electricity network. Critical temperatures are monitored to ensure the integrity of the stored product. This allows Norish to earn extra revenue without disrupting its normal business operations."[208]

The Park Plaza Westminster Bridge Hotel in London provides an example of a different type of consumer participating in DSR, through its arrangements with the aggregator KiWi Power:

> "Kiwi Power worked with Park Plaza Westminster Bridge London to install meters providing real time electricity readings to help identify energy usage within the site which could be turned down during peak periods and would not negatively impact the guest experience … When the National Grid initiates a demand response STOR programme, KiWi calls upon the property to turn down these assets to pre agreed and tested levels for up to two hours. KiWi's technology aggregates this rebalanced power supply with other sites to relieve the demand on the Grid. This spares the National Grid calling upon less efficient and polluting solutions to deliver additional energy nationwide."[209]

This can deliver 60 to 300 kWs of turn down at each event. Since installation in 2013 the hotel has been called on to turn down for a total of 9 hours, delivering 3035 kWh back to the National Grid. Further information on all of these case studies is provided in the written evidence volume.

Source: Written evidence from Flexitricity, KiWi Power and Northern Power Grid.

207 Written evidence from Northern Powergrid (REI0059)

208 Written evidence from Flexitricity (REI0058)

209 Written evidence from KiWi Power (REI0057)

163. In the future, it is envisaged that other large consumers, such as supermarkets, will participate, for example by temporarily turning off refrigeration facilities.[210] Honeywell pointed to opportunities for UK water companies, who are responsible for around 1% of the UK's total electricity consumption, to participate in DSR as they do elsewhere in the world. [211] The technology to make it possible for a wider range of consumers to participate in DSR is progressing and the role of aggregators is becoming increasingly important:

> "DSR has required manual systems to curb electricity demand in response to a signal provided by National Grid. New technology based on Information and Communication Technology (ICT) is now in the market that enables DSR to be automated, with an electronic signal being sent by the system operator via companies that act as 'aggregators' of DSR. This technology is cheaper and much more applicable to a variety of commercial activity in the service sector as well as in the industrial sector. Examples include aggregators delivering DSR through office blocks that instruct their building management systems to turn down their air conditioning temporarily in response to a signal. The high thermal storage provided by the concrete in these buildings means that occupants do not notice for short periods. The aggregators get paid by the system operator and in turn pay the office block for providing the service."[212]

164. As described in Box 6, aggregators operate by working with companies, which are able to offer smaller amounts of DSR. By aggregating the contribution of many smaller consumers, aggregators are able to enter into contracts with National Grid to provide DSR. For example, to participate in STOR a minimum of 3 MW DSR must be offered, which is more than many individual companies are able to provide.

Domestic DSR

165. The use of DSR domestically is a new area which will be made possible by the introduction of smart meters. Only around 900,000 smart meters have been rolled out to date.[213] The Government explained how smart meters would enable consumers to contribute to DSR:

> "… the Government expects that the trend towards ICT enabled automated DSR will lower costs and allow consumers of low amounts of electricity to participate in providing increasingly higher amount of DSR. In particular, the roll-out of 53 million smart electricity and gas meters in homes and small businesses across Great Britain by the end of 2020 will provide a mechanism for individual domestic and small business consumers to participate in providing DSR …
>
> The smart metering technology which facilitates DSR will form part of the 'Smart Grid', whereby an interconnected network of smart meters, smart heating controllers and smart appliances that will enable the

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210 Written evidence from BDO LLP (REI0011); Q 8 (Dr Simon Harrison)

211 Written evidence from Honeywell (REI0019)

212 Written evidence from the Government (REI0040)

213 Oral evidence taken before the House of Commons Energy and Climate Change Committee, 16 December 2014 (Session 2014–15), Q 170 (Baroness Verma, Parliamentary Under-Secretary of State, DECC)

benefits of time-of-use (ToU) tariffs and DSR to be rolled out to all electricity consumers using a high degree of automated control."[214]

166. Mike Calviou, Director of Transmission Network Service, National Grid, considered what might be achievable in the longer term using smart, controllable technology:

> "[In] the longer term, looking at various smart grid technologies, we would hope and expect to use the ability of smart controllable technology to continue to grow that demand side. Ultimately, in the future, if we could have access all the way down to domestic demand—whether that is electric vehicle demand, fridges and freezers in people's homes or whatever—and the ability to switch and profile that as a service, then that would give us a great tool with which we could help balance the system in the future. Some of this is probably getting five or 10 years into the future."[215]

167. Although smart meters are essential for domestic DSR, there have been delays in their roll out, which have resulted in additional costs. It is clear that appropriate pricing structures will be needed to encourage consumers to use off-peak electricity:

> "The smart metering roll-out will create new opportunities for parties to use the electricity system more effectively. Suppliers will have access to accurate consumption data and would therefore be able to offer time of use tariffs that reward consumers for shifting demand away from times of system stress."[216]

168. We do note, however, that some consumers may find it difficult to change their behaviours:

> "The evening period in the domestic setting is often a very intense frantic period with lots of activity going on and if you are pushing prices up very significantly during that period, all you could be doing is penalising consumers who cannot necessarily just reposition stuff."[217]

169. Nevertheless, we consider the advent of smart meters to be crucial in the development of domestic DSR and it is very disappointing that there have been delays in their roll-out. We were encouraged, however, that the Government, in a recent letter to the Chair of the House of Commons Energy and Climate Change Committee, Tim Yeo MP, was able to provide some reassurance regarding the roll-out, especially on the importance of smart meter functionality—the mandate for suppliers to offer consumers a sophisticated in-home display rather than consumers having to use smart phones or tablets to access energy consumption data. This will be vital, international evidence

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[214] Written evidence from the Government (REI0040)

[215] Q 57

[216] Written evidence from Ofgem (REI0044)

[217] Q 120, (Professor Gordon Walker)

shows, in "enabling consumers to change their behaviours, reduce energy consumption and save money."[218]

170. **Smart meters, produced with appropriate functionality, will be essential in facilitating greater use of Demand Side Response in homes. We recommend that the Government ensures that no further delays occur in the roll out of smart meters and that Parliament is updated periodically about progress towards the 2020 target. Communicating the benefits of smart meters and incentivising consumers will be imperative and, to this end, we recommend that the Government, in partnership with industry, develops a comprehensive communications strategy with the aim of maximising the potential of smart meters.**

Policies to encourage DSR

171. The Government has argued that transitional arrangements are needed to help new DSR providers that are not yet advanced enough to compete against generation in the main Capacity Market. The Government told us that it hoped to grow levels of DSR:

> "During winter 2013/14 Triad period[219], typical DSR levels experienced were 1.2GW and on occasion up to almost 2.0GW. We hope to grow levels of DSR through the Capacity Market. Evidence from the US shows that in 2012 DSR delivered 6% of peak capacity across the US and the PJM[220] Capacity Market alone has brought forward about 15GW of DSR over 10 years."[221]

172. National Grid accepted that more needed to be done to grow DSR:

> "There have been recent positive developments in demand side but we recognise that more needs to be done. In order to successfully encourage greater demand side participation there needs to be a clear, stable policy framework that is supported by delivery mechanisms that enable smart technology and initiatives to drive greater consumer awareness and participation."[222]

173. Mike Calviou, Director of Transmission Network Service, National Grid, said that discussions were ongoing about how the Capacity Market could facilitate DSR:

> "Going forward, looking at the capacity mechanism, we would want more demand side to be able to play in that. There is a lot of discussion going

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218 Letter from Baroness Verma, Parliamentary Under-Secretary of State, DECC, to Tim Yeo MP, 'Progress on the smart meter roll-out' (January 2015): http://www.parliament.uk/documents/commons-committees/energy-and-climate-change/Smart-meters-correspondence-from-Baroness-Verma.pdf [Accessed February 2015]

219 The Triad refers to the three half-hour settlement periods with highest system demand between November and February, separated by at least ten clear days.

220 PJM—Pennsylvania, New Jersey and Massachusetts—is a regional transmission organisation operating in 13 states in the eastern US. It operates one of the few capacity markets that use DSR as a resource to balance the network.

221 Written evidence from the Government (REI0040)

222 Written evidence from National Grid (REI0017)

on with the Government about how to make the capacity mechanism rules sympathetic and help facilitate demand side to play. There have been some challenges and some debate and I think we will probably see some of the rules around demand-side participation evolve over time to help them come in."[223]

174. Such discussions, and the possibility of the rules around demand side participation evolving, are to be welcomed as we heard that the current policy framework was not adequate: "policy and market arrangements for electricity are insufficiently focussed on the demand side."[224]

175. Professor Mitchell, Exeter University, argued that the US led Europe on DSR, and noted that DSR was able to compete on an equal basis with generation in the PJM (Pennsylvania, New Jersey and Massachusetts) market:

> "One way that the US is far better than all of Europe is to do with demand-side response within markets. Pennsylvania, New Jersey and Massachusetts—PJM—is a market that has bits of 13 states and covers 51 million customers, which is about the size of Britain. I just have this quote for you so that you see the picture. The demand [side] response in that market is able to compete in exactly the same way as supply, so it goes into the same market. For 2010, which was for capacity in 2013–2014, it saved those 51 million customers $12 billion and it paid the equivalent of £430 million, or 10 gigawatts of demand side response. That is in PJM. That is about 12% of projected demand. You bid in to not use it, rather than to supply it. If you have a flexible demand system, then when you have issues of capacity or resilience problems, you are much more able to deal with it, it is cheaper for customers and it is better for security. PJM is the best. That is about 12% of demand roughly, but the average in the US across those 50 states is still 6%. If you look at our system here in the UK, which is a market-wide system, it is about 1% of demand and you cannot bid in in the same way. It is a very poor system in relation to that."[225]

176. The ability of DSR to compete with generation on an equal footing is important in encouraging the development of this technology. We therefore note with some concern that the length of contracts offered for DSR are limited to one year. This contrasts with contracts for generation, which may be up to 15 years. It was argued by Michael Ware, Partner for New Energy and Environment, BDO LLP, that this is impeding greater participation of DSR in the Capacity Market:

> "Demand-side response contracts [in the capacity auction] are much shorter than they are for generation, which is a disincentive for investors to invest in demand-side response. For industrial and commercial users, this is an investment requirement. The aggregators have approached us in the past to say, 'We want to raise £10 million, £20 million or whatever to roll out demand-side response technology across a customer base of commercial and industrial users', but the payback is so compressed

[223] Q 57

[224] Written evidence from the DEMAND Centre (REI0037)

[225] Q 140 (Professor Catherine Mitchell)

because the amount of capacity they can sell into the auction is limited to a year. I think that is an obvious amendment to make to the policy that would bring in investment much more quickly."[226]

177. Honeywell reinforced this view:

"DSR Aggregators need the surety of long term DSR provision to enable business models to be attractive and so long term contracts need to be offered, well beyond the one year term currently proposed under the Capacity Mechanism, justifying the significant investment they need to make in a DSR solution infrastructure."[227]

178. Ofgem acknowledged that there was a need for the Government to re-examine the length of contracts available for DSR in the Capacity Market:

"… there are still some questions, particularly around the duration of contracts that are up for grabs for demand-side response in the main capacity market, which are limited to one year. There is some thinking to be done by the Government about whether the same principles that have been used to decide on the duration of capacity market contracts for generation should also be applied to demand-side response."[228]

179. It was put to us that there was greater potential for the public sector to play a leading role in DSR, and that at present this potential was not being realised. Michael Ware argued that:

"Where the public sector could play a very significant role is to be an exemplar for demand-side response. A recent study by the Cabinet Office, taking the whole public sector estate, particularly health, showed that less than 10% of the public sector were looking at any form of demand-side response and the majority of respondents—over 60%—had no plans to do so whatsoever for the foreseeable future …

… there is no overarching target or requirement upon the public sector to either generate its own energy or to implement demand-side response. This is purely speculation, but I suspect that, as a manager in a public sector environment faced by competing demands upon capital, demand response and micro-generation are probably lower down on my list of priorities than other constraints because the payback period is much longer and the impact is less visible."[229]

180. It is clear to us that the potential of DSR is not being fully realised, though we acknowledge that the Government does seem to be alive to its possibilities. Above all, the Government must ensure that policy does not disadvantage DSR, or it risks fostering unnecessary high-carbon generation capacity at the expense of innovative demand-side measures. More broadly, the public sector should aim to provide greater leadership. The introduction of smart meters represents a very important evolutionary step for domestic DSR and it is imperative that the roll out of smart meters is delivered to time.

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226 Q 118 (Michael Ware)

227 Written evidence from Honeywell (REI0019)

228 Q 181 (Rachel Fletcher)

229 Q 115 (Michael Ware)

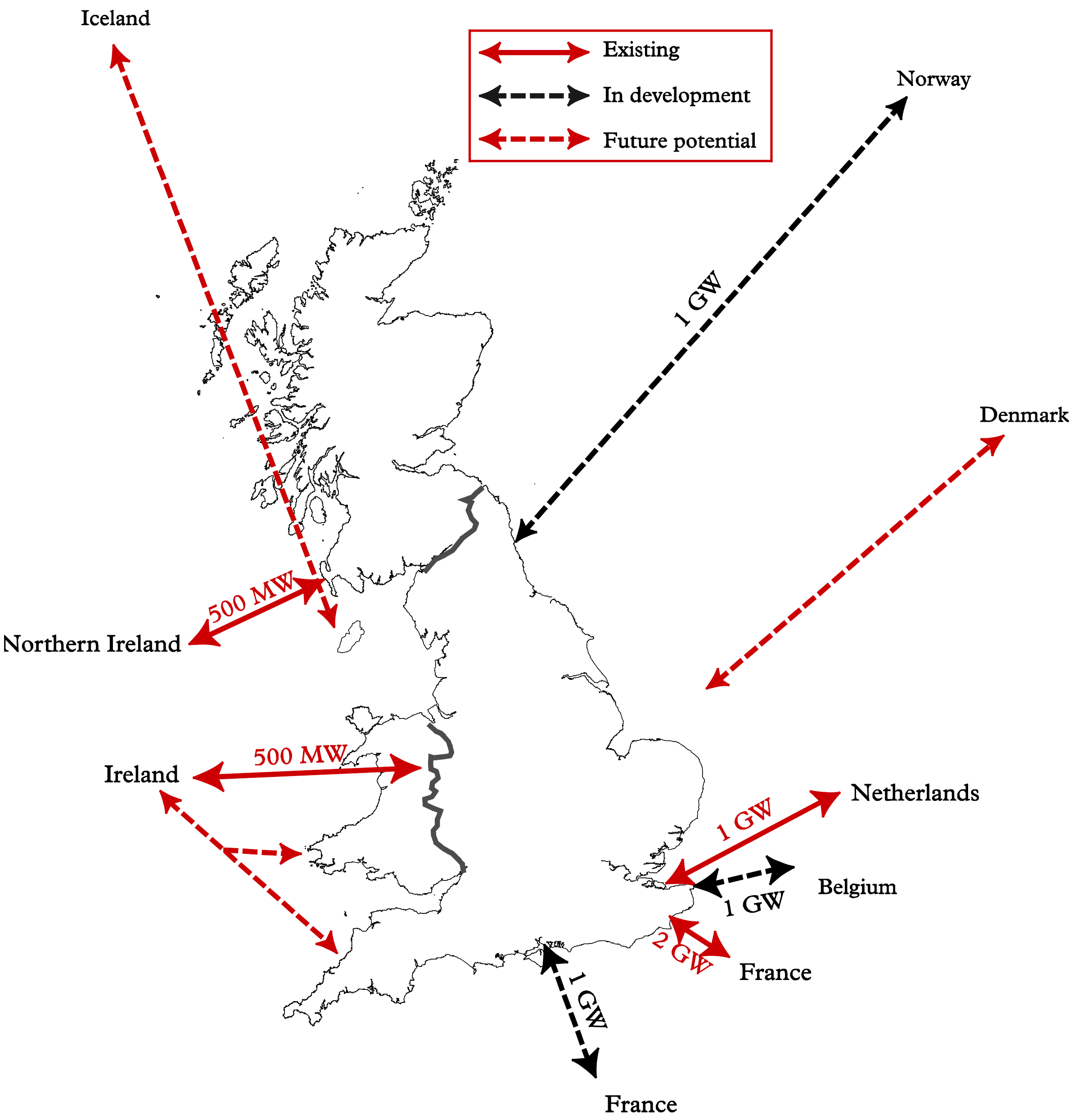
181. **Demand Side Response (DSR) offers significant potential for balancing supply and demand. We recommend that the Government ensures that DSR is not disadvantaged in the Capacity Market relative to generation. To this end, we recommend that the length of DSR contracts in the Capacity Market should be brought into line with generation.**

182. **We recommend that the Government conducts and publishes detailed assessments of what Demand Side Response (DSR) could potentially achieve. In addition, we recommend that the Government develops and publishes a plan, which includes specific targets, for the public sector to implement Demand Side Response measures and so set an example.**

CHAPTER 6: INTERCONNECTION

183. Interconnectors are transmission cables which allow the transfer of electricity between countries. Electricity flows from the market with lower prices to the market with higher prices. Currently, Great Britain has four interconnectors providing 4 GW of capacity, representing around 5% of generation capacity.[230]

Figure 7: Interconnection Map



Source: Adapted from National Grid, Interconnectors *(May 2014): http://investors.nationalgrid.com/~/media/Files/N/National-Grid-IR/factsheets/2014/interconnector.pdf and Ofgem,* Electricity Interconnectors factsheet *(May 2014): https://www.ofgem.gov.uk/ofgem-publications/87961/electricityinterconnectorsfactsheet.pdf [accessed February 2015].*

184. In 2002, the European Council set a target that all Member States should have electricity interconnections equal to at least 10% of their generation capacity

230 Ofgem, *Electricity Interconnectors factsheet* (May 2014): https://www.ofgem.gov.uk/ofgem-publications/87961/electricityinterconnectorsfactsheet.pdf [accessed February 2015]

by 2005.[231] Great Britain was not alone in failing to meet this target; five years after this deadline Great Britain and several other Member States still had less than 10% interconnection. In 2011, the European Council recognised the importance of "a fully functioning, interconnected and integrated internal energy market," to allow energy to flow freely and establish a more reliable and less costly energy system.[232] It was agreed that actions to enable the internal energy market should be completed by 2014. Increased interconnection was one priority in achieving an internal energy market. On 25 February 2015, the European Commission adopted its strategy for a European Energy Union. This included an Interconnection Communication,[233] which set out the measures needed to achieve a target of 10% electricity interconnection by 2020, the minimum necessary for electricity to flow and be traded between Member States. 12 EU Member States do not currently meet the EU's minimum interconnection target, including the UK.[234]

185. Plans are now in place to increase interconnection between Great Britain and other countries. Dr Charlotte Ramsay, Project Director for NSN Link, National Grid, explained that there were plans for interconnection capacity to double over the next decade:

> "Things have been developing quite significantly over the last 12 months … we are relatively poorly interconnected at the moment in relation to other countries in Europe, but there are plans over the next 10 years to be seeing probably around a doubling of our interconnection capacity. There are a number of projects that are on the verge of their final investment decision, so moving from development into the delivery stage, and that has been brought forward by a step change in the regulatory framework for interconnection."[235]

186. Increased interconnection, we were told, could bring significant benefits and enhance resilience. Ofgem stated that: "interconnectors play an important role in a resilient GB network as, in times of system stress, electricity can be imported from other markets. There are plans for a significant increase in new interconnection and this will help support future security of supply."[236] Professor Goran Strbac, Faculty of Engineering, Imperial College London, told us that analysis he had been involved in suggested that "the UK will benefit significantly from interconnection."[237]

187. National Grid pointed to a range of potential benefits that could be realised:

> "National Grid's analysis shows that each 1GW of new interconnector capacity could reduce Britain's wholesale power prices up to 1–2%. In total 4–5GW of new links built to mainland Europe could unlock up to

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231 Energy and Climate Change Committee, *A European Supergrid* (Seventh Report, Session 2010–12, HC 1040)

232 European Council, *Conclusions on Energy* (February 2011): https://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/trans/119253.pdf (accessed February 2015)

233 Energy Union Package: Communication from the Commission to the European Parliament and the Council: Achieving the 10% electricity interconnection target, COM(2015) 82 final

234 Cyprus, Estonia, Ireland, Italy, Lithuania, Latvia, Malta, Poland, Portugal, Romania, Spain, United Kingdom.

235 Q 111 (Dr Charlotte Ramsay)

236 Written evidence from Ofgem (REI0044)

237 Q 111 (Professor Goran Strbac)

£1 billion of benefits to energy consumers per year, equating to nearly £3 million per day by 2020[238]. Greater electricity interconnection could yield a range of potential benefits to the UK economy and GDP. Through net imports, lower electricity prices to business consumers would reduce input costs, enhance competitiveness and boost household disposable incomes and domestic spending. Through net exports, there is also a significant opportunity for British generators in using interconnectors to access a much wider consumer base across mainland Europe and thus earn additional revenues."[239]

188. Dr Konstantin Staschus, Secretary General, European Network of Transmission System Operators for Electricity, noted that interconnection would be important in helping to balance the system as the penetration of intermittent renewables extended:

> "[there is an] increasing importance of interconnectors for the future as more and more renewable energy comes into the system here and elsewhere in Europe, more interconnection will have to be built to keep the transition towards low-carbon resources affordable and as resilient as possible."[240]

189. Dr Charlotte Ramsay put it to us that increased interconnection with countries, such as Norway, with its surplus of hydropower generation, could prove particularly beneficial:

> "… an interconnector to Norway, which is a predominantly hydro system, would have more capacity value than a connection to Ireland because, as has been pointed out, the Northern Irish system may be in more trouble than ours and the Irish system is much more similar to the UK system."[241]

Similarly interconnection with Iceland could be beneficial due to its geothermal energy sources. [242]

190. The desirability of increased interconnection, however, was not a unanimously shared view. It was suggested to us by Energy UK and EDF Energy that not enough was known about how interconnectors will function, particularly in terms of what would happen if a number of interconnected countries experienced system stress at the same time:

> "Increased interconnection with the rest of Europe can improve resilience but as the flows are determined by market prices, there is a prospect of exports at time of system stress if it coincides with a similar situation in interconnected markets. These risks and the powers of Governments to restrict interconnector flows need to be better understood …

238 National Grid, *Getting More Connected* (March 2014): http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=32371 [accessed February 2015]

239 Written evidence from National Grid (REI0017)

240 Q 140 (Dr Konstantin Staschus)

241 Q 104

242 Iceland has both geothermal and hydro resources. We were told that interconnection with Iceland was "forbidding but not impossible." (Q 86, Professor Gordon Hughes)

For example, high pressure systems in winter, which can cover the whole of North-west Europe, could create widespread high demand for heating at the same time as significantly reducing wind output over periods of up to two weeks. Building interconnectors to a number of different countries could mitigate this risk. Nevertheless, there remains a question about whether the market can be circumvented to stop exports."[243]

"… interconnection will only help to contribute to security of supply if there is spare capacity in neighbouring countries when it is needed. As the level of interconnection between GB and neighbouring systems grows, it will be increasingly important to consider what would happen in the event of a stress event affecting a number of interconnected countries simultaneously."[244]

191. We were told, however, that in an emergency the interconnector could be manipulated so that electricity could flow in the right direction. Dr Charlotte Ramsay, Project Director for NSN Link, National Grid, stated:

"In terms of emergency situations, let us say the flow is going in a different direction because prices up to real time have dictated flow in a different direction. Because of the arrangements that we have in place, because of the market arrangements that are in place, the interconnector can be turned round to be able to provide flow in the right direction, to be able to support the system."[245]

192. Rachel Fletcher, Senior Partner for Markets, Ofgem, confirmed that such arrangements were in place:

"… the system operator [National Grid] has contracted for what they call emergency services on the interconnector. So if we are in a particularly tight situation, National Grid can call on emergency interconnector support into Great Britain, but that would not be a normal functioning of the market; it would be National Grid intervening and taking emergency measures."[246]

193. While we welcome these clear statements from National Grid, supported by Ofgem, it is a source of concern that there appears to be some confusion about what can be done if a number of interconnected countries experience system stress at the same time.

194. Ofgem have made recent improvements to the regulations[247] in order to support investment in interconnectors: "We have developed a regulatory regime for new electricity interconnectors that will help to ensure that efficient levels of investment are brought forward in a timely way."[248] It appears that

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243 Written evidence from Energy UK (REI0034)

244 Written evidence from EDF Energy (REI0030)

245 Q 105

246 Q 181

247 Known as the 'cap and floor' approach: https://www.ofgem.gov.uk/publications-and-updates/decision-roll-out-cap-and-floor-regime-near-term-electricity-interconnectors

248 Written evidence from Ofgem (REI0044)

the new regulations have been successful in bringing forward investment. Dr Charlotte Ramsay told us that:

> "… the decision from Ofgem in the summer time to bring forward their innovative cap and floor regime for interconnection, [means] that there is now a clear pipeline of interconnector investment that is looking to come forward between now and 2020."[249]

195. It seems, however, that there may still be limits to commercially optimal investment in interconnection. Professor Catherine Mitchell, University of Exeter, claimed that regulation was outdated and not fit for today's challenges:

> "One of the reasons why we have very high wholesale prices is that, I think, 2% of our total capacity is interconnected, and the Commission wants to have roughly 10%. In my view, and I am sure many people would say it is very simplistic, I think it has been in the interests of the large generators in Britain not to have interconnectors, because if you were to have interconnectors then cheaper electricity would come in from the continent. The regulation of the way that we fund our interconnectors has always been that it is a market system based on the interconnector itself, as compared to the whole of the rest of Europe, which sees interconnectors as part of the transmission system. So they go along to their regulator, their regulator says you can have the money to do that and then they socialise the cost of the interconnector over the cost of electricity. We have now been forced to go down a third way because our British system has not fitted with the European system, and now we have some fudge between a market and a regulated mechanism. Overall, this is part of the issue that I am talking about. We have a set of regulations that are based on older technologies and we need to move into regulations that fit the world that we live in."[250]

196. Professor Goran Strbac put it to us that there was a problem insofar as "the offshore connection developments and interconnection are different businesses and they are not coordinated."[251] In his view, this left National Grid unable to make commercially optimal investments. For example, it could make sense, commercially, to route the planned GB-Norway interconnector via Dogger Bank in the North Sea in order to take advantage of the offshore wind farms developed there. Professor Strbac also expressed concern that interconnection was not initially included in the Capacity Market:

> "… the Panel of Technical Experts for DECC that is scrutinising the implementation of electricity market reform and the capacity mechanism […] expressed a concern that interconnection has not been included in this."[252]

197. Although interconnectors were not included in the first Capacity Market auctions, the Government announced on 2 December 2014 that interconnectors would be eligible to participate in the Capacity Market from 2015—for the second four year ahead auction. There is concern, however, that

249 Q 111 (Dr Charlotte Ramsay)

250 Q 145 (Professor Catherine Mitchell)

251 Q 112 (Professor Goran Strbac)

252 Q 111 (Professor Goran Strbac)

over procurement of generation capacity could inhibit investment in interconnectors. Professor Strbac asserted:

> "… another concern we have is that we might in fact potentially buy too much generation, in which case we may not necessarily benefit from interconnection—the benefits may not be possible to realise because we will have already spent the money, which should not have been spent."[253]

198. Professor David Newbery, Cambridge University, and Professor Michael Grubb, University College London, warned that:

> "The risk of over-procurement [in the Capacity Mechanism], particularly of new conventional capacity on long-term contracts, is that it drives up the costs to consumers; undermines renewable energy by implicitly transferring financial support from renewables to conventional generators; and impedes the European Single Market's aim at a single pan-EU electricity market, including by weakening the business case for other options, including future interconnectors that are widely agreed to be increasingly important as the share of intermittent electricity rises."[254]

199. In summary, interconnection seems to have an important role to play in resilience. There is, however, at least a perception that the evidence base for how interconnectors will behave is lacking. In addition, although Ofgem has taken steps to improve the regulatory environment, more could be done to enable effective commercial decisions to be made.

200. **There is a worrying lack of clarity about what options exist if a number of interconnected countries experience system stress simultaneously. We recommend that the Government publishes an analysis of the effects of interconnectors on UK electricity resilience under a broad range of scenarios. This analysis should include an assessment of how interconnectors might be used at times when the system is under stress. It should specifically assess the case for restrictions / agreements to be put in place with other countries at times of system stress if there is evidence that resilience could be compromised.**

253 Q 111 (Professor Goran Strbac)

254 Written evidence from Professor David Newbery and Professor Michael Grubb (REI0026)

CHAPTER 7: ELECTRICITY STORAGE

201. There are a range of electricity storage technologies at various stages of development which are suited to different applications at different scales.

Box 7: Electricity Storage

Storing electricity to be used on demand has the potential to be an important backup to intermittent renewable generation, as well as reducing costs to consumers. Storage technologies—which include batteries (chemistry batteries, flow batteries and capacitors), flywheels, compressed air storage, thermal and pumped-hydro—are suited to different applications on a range of scales. Currently, only pumped-hydro storage is viable at scale. Pumped storage facilities store energy in the form of water in an upper reservoir, pumped from another reservoir at a lower level at a time of low electricity demand. At times of peak demand, water is released from the upper reservoir through turbines to generate electricity. Further significant increase, however, seems unlikely due to lack of additional suitable sites—though it would be misleading to assert that there is no potential. Scottish Power, for instance, is investigating the feasibility of more than doubling the output of its pumped storage plant at Cruachan in Argyll to 1040 MW. Thermal energy storage, while not strictly an electricity technology, can provide flexibility for the overall energy system—e.g. surplus electricity could be converted to heat and then stored as such (in water, molten salts, bedrock etc.) until needed. The Government have identified energy storage as one of the "eight great technologies." DECC and Ofgem have supported some electricity storage demonstration projects in the UK.[255]

202. Electricity storage could play an important role in enhancing resilience as it could help to balance supply and demand. Currently, the costs of electricity storage technologies are high. We were told, however, that storage could potentially be a transformative technology:

> "Electricity storage has great potential to be a game changer in terms of balancing electricity supply and demand if it can be brought forward as a cost effective proposition. Energy storage has the potential to take excess generation such as on a windy or sunny summer day, and store it in multiple places from large pumped hydro stations down to batteries within homes and everything in between; potentially becoming a game changer."[256]

> "If economic electricity storage, able to store large amounts of energy, were developed, it would be a 'game changer' in terms of improving resilience, as it would remove some of the challenges related to managing intermittency and reducing the requirement for backup generation and use of the network."[257]

[255] Written evidence from the Electricity Storage Network (REI0012)

[256] Written evidence from National Grid (REI0017)

[257] Written evidence from Energy UK (REI0034)

> "For me, the alchemy for energy policy is storage. If we could find cheap ways to store electricity in particular but other forms of energy as well, that would be a massive breakthrough."[258]

203. Scepticism was expressed, however, as to the speed at which the costs of electricity storage would come down to make this a commercially viable technology:

> "Electricity storage could potentially be a game changing technology for the industry if it were developed to the point where very large volumes of energy could be stored at a commercially viable cost; this would provide a means of managing some of the challenges associated with intermittency. However, this development does not appear likely in the short or medium term. Large pumped hydro schemes exist, but none have been built in recent years. The introduction of the capacity mechanism may incentivise any remaining potential sites to come forward for investment."[259]

204. Anthony Price, Director, Electricity Storage Network, told us that currently the electricity system "contains about 3 gigawatts of electricity storage … against a peak load of, say, around 70 gigawatts."[260] We note that this is a small amount of storage. Energy UK said that increasing the use of storage required:

> "… a radical reduction in cost and increase in total potential storage scale, whether the storage is deployed in many smaller sites or a few very large ones."[261]

205. As noted above, at present electricity storage is in the form of pumped storage (i.e. hydropower), which is the cheapest form of storage. Although pumped hydro could be used to generate electricity to help balance the grid, we heard that currently it is under-used in this respect. Anthony Price argued that:

> "… frequency regulation requires about 1 gigawatt of plant and fast reserve typically about 500 megawatts or 600 megawatts. That provision could be met entirely by our current pumped hydro in GB … I am informed that our pumped storage is not fully utilised in this area, mainly because of the commercial arrangements … We do not use it for providing frequency or providing fast reserve in its entirety because the contracts between the storage providers and the system operator are not sufficiently favourable for that to take place … as I understand it, [pumped storage operators] need to recover a certain amount of their costs and, therefore, they put in place contracts either through tendering or through legacy arrangements to provide their services to the system operator, and if other providers of the same services can do so more cheaply then the contract will go to other providers."[262]

206. As noted in Box 7 above, there are several other different types of storage technologies. These are at different stages of technological development and

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258 Q 195 (the Rt Hon Ed Davey MP)

259 Written evidence from EDF Energy (REI0030)

260 Q 103

261 Written evidence from Energy UK (REI0034)

262 Q 103

"further innovation and development are needed to make energy storage cost-effective for wide deployment."[263] The Government has identified energy storage as one of its 'eight great technologies'[264] and is funding R&D in this area:

> "The LCICG's (Low Carbon Innovation Coordination Group) 2012 Technology Innovation Needs Assessment (TINA) for Electricity Networks & Storage also concluded that 'while some of this innovation potential could be realised through 'learning-by-doing' we [LCICG] expect that over half the cost reduction potential to 2050 would be driven by RD&D'. For storage technology specifically, the TINA indicates that innovation in energy storage technologies has the potential to yield estimated total system cost savings of £5 billion (range: £2–10 billion) up to 2050."[265]

207. Craig Lucas, Head of Engineering, DECC, told us that funding has specifically been made available for demonstration projects:

> "… the challenge is to get those technologies up the technology-readiness curve and ultimately drive the cost down. That is why we put £20 million of innovation funding into demonstrating some of the different technologies at scale to see where the cost reduction potential is, because technically they are all there—you can technically integrate them to the grid—but they are still too expensive."[266]

208. Whilst this investment is welcome, we were told that more resources needed to be put into demonstration facilities. Anthony Price, Director, Electricity Storage Network, asserted:

> "We are investing a reasonable sum of money. It is not as much as the Americans are investing. But the area where we are falling short is that we have not put as much money into demonstration as the Americans have done. The multi-hundreds of millions that the Americans have put in has included sufficient money for the technologies to be demonstrated at grid scale. The American Government has supported battery installations of 20 or 40 megawatts. We have not done that. In fact, we have the rather perverse situation that one Government department is putting money into research and development—typically at our universities—but we struggle with another department to try to create a market framework where those technologies can be put out and demonstrated that they work."[267]

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263 Written evidence from the Government (REI0040)

264 The Chancellor, Rt Hon George Osborne MP, first set out the eight great technologies in a speech to the Royal Society in November 2012. In this speech, he challenged the scientific community to lead the world in eight areas: big data and energy-efficient computing; satellites and commercial applications of space; robotics and autonomous systems; synthetic biology; regenerative medicine; agri-science; advanced materials and nanotechnology; energy and its storage.

265 Written evidence from the Government (REI0040)

266 Q 24

267 Q 108 (Anthony Price)

209. The Electricity Storage Network do not therefore think that the principal focus should be on the need for more R&D, but rather, it should be fixed on the need for creating suitable market conditions:

> "Electricity storage is ready and available today. We do not need advances in the technology but we do need advances in market conditions to encourage further deployment of storage technologies."[268]

> "Current market conditions in the UK are holding back the widespread deployment of electricity storage technologies. In other country such as the U.S., the value of storage technologies are being realized and Government has set mandates and provided tax reliefs to encourage the levels of storage to grow. In Germany there is an incentive for distributed storage associated with PV generation to manage network and allow microgenerators to avoid buying electricity at peak demand (maximize self-consumption by shifting midday peak in generation to provide energy in the evening)."[269]

210. It was suggested to us that the Capacity Market was not the appropriate tool to incentivise investment in storage. Michael Ware, Partner for New Energy and Environment, BDO LLP, argued that storage would be better placed under the contracts for difference regime rather than in the Capacity Market:

> "At the moment DECC have placed it [storage] within the capacity auction, almost as an afterthought it feels to me, whereas I feel it would have been much better placed under the renewables umbrella of contracts for difference [CfD] because one can get much more certainty, from an investment point of view, around investing in storage. If it is placed in the capacity auction I am asking my battery-based storage system to compete with the established technologies when I am not at that point and I get much shorter contracts than I do for generation. Under the CfD regime, I am competing with less established technologies in the sense of renewables and much longer contract periods. I think that is much more attractive to investors. The role of the Government there is promoting storage and promoting innovation in storage by placing it under the CfD regime rather than the capacity regime."[270]

211. Energy UK argued that changes to industry codes would also be needed:

> "Changes to the industry codes that govern the granting of access to and use of grid systems are likely to be required to change, as they do not currently take adequate account of storage. Users of grid systems are categorised as either generators or consumers; storage is neither and the regulated industry codes need to take account of its unique characteristics in order to give it the opportunity to deliver long term benefits to consumers."[271]

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268 Written evidence from the Electricity Storage Network (REI0012)

269 *Ibid.*

270 Q 119 (Michael Ware)

271 Written evidence from Energy UK (REI0034)

212. It appears that the Government has taken an important step towards encouraging the development of electricity storage by agreeing a target for new storage on the grid by 2020:

> "A 2GW target of new storage on the UK grid by 2020 has been proposed by the Electricity Storage Network (ESN) and is now agreed by industry and government."[272]

213. **In addition to investing in Research & Development in electricity storage, the Government and Innovate UK should ensure that high potential demonstration projects are adequately funded. In addition, the Government should take steps to improve the market framework so as to stimulate investment in electricity storage. As a step towards improving the market framework, we recommend that the Government examines whether electricity storage should be placed under the Contracts for Difference regime rather than in the Capacity Market and reports its findings.**

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272 Written evidence from the Electricity Storage Network (REI0012)

CHAPTER 8: FLEXIBLE GENERATION

Intermittent renewables and the effect on resilience

214. The transition to a low carbon electricity system presents challenges for resilience. Existing technologies provide three main ways of achieving decarbonisation of electricity generation: renewables, nuclear and using carbon capture and storage with fossil fuel generation. Renewables and nuclear generate a much less flexible supply of electricity than fossil fuel plant. Nuclear provides a constant base load, but generation cannot be increased efficiently in response to peaks in demand. Newer reactors may, however, offer greater flexibility. The amount of electricity generated by renewables varies depending on factors such as weather conditions.

Box 8: Wind, Solar and Hydroelectricity

Wind. Wind turbines generate electricity by using the wind's kinetic energy to turn propellers, which in turn spin a generator to create electricity. Wind farms can be situated either onshore or offshore. As onshore wind farms tend to meet resistance from local communities, and offshore wind speeds are generally higher and more reliable, there has been an increasing effort to install and support offshore wind. The capital cost of offshore wind farms is, however, also higher. The UK currently has 8 GW of onshore capacity and 4.4 GW of offshore capacity installed.

Solar. Photovoltaic (PV) panels generate electricity from the sun's energy. The UK photovoltaic market grew rapidly following reductions in the cost of PV panels, and the introduction of the Feed-in-Tariff (FiT) in 2010. From 2013 to 2014 the solar photovoltaic installed capacity increased by 74% to 4.5 GW.

Hydroelectricity and pumped storage. The kinetic energy of falling or flowing water is used to rotate turbines that in turn spin a generator to produce electricity. There is currently 1.7 GW of installed capacity in the UK. A significant further increase in capacity may be unlikely due to a lack of suitable sites.

Source: DECC, Energy trends statistics—Section 6: Renewables: (December 2014): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/386837/6_Renewables.pdf *[accessed February 2015]*

215. Such intermittency has the potential to affect the resilience of the system. As seen in previous chapters of this report, there are a range of tools for managing intermittency (e.g. interconnection, DSR, storage), which will involve significant changes to the electricity system, and as noted in Chapter 2 of this report, it will be imperative to manage the system as a whole.

216. Ofgem highlighted the responses which might be required in the coming years as the generation mix alters:

> "The changes in the generation mix in GB over the coming years will likely represent a fundamental change to the way the system operates. Increased intermittency will likely make it more challenging for market participants to balance their overall positions and, ultimately, for the SO [system operator] to balance the system. This means that the SO's role may need to evolve, and a more diverse set of tools to operate the energy

system could be required. In the future, DSR, interconnection and storage are expected to take a bigger role as the volume of intermittent generation increases."[273]

217. Decarbonisation of electricity generation is expected to increase electricity prices. In 2014, DECC calculated that its energy and climate change policies[274] were expected to have the following effects on retail electricity prices:

Table 2: Estimated average impact of energy and climate change policies on household electricity prices

	2014	**2020**	**2030**
Price impacts (real 2014 £/MWh)			
Average electricity price without policies	140	141	154
Average electricity price with policies	164	194	216
Percentage of total price accounted for by policies	15%	27%	29%

Source: adapted from DECC, Supplementary Tables—Estimated impacts of energy and climate change policies on energy prices and bills *(November 2014): https://www.gov.uk/government/publications/estimated-impacts-of-energy-and-climate-change-policies-on-energy-prices-and-bills-2014 [accessed February 2015]. The analysis is based on DECC's central fossil fuel price scenario.*

218. Despite these increases in retail electricity prices, DECC calculated that the average household electricity bill would in fact be lower because of its energy efficiency policies. DECC argued that: "By 2020, the impact of policies on energy prices is, on average, expected to be more than offset by the impact of policies which improve energy efficiency by helping households (and also businesses) reduce energy consumption."[275] Energy efficiency policies were estimated to reduce the average electricity bill by £100 in 2014 and are forecast to reduce bills by £173 in 2020 and £155 in 2030.[276] We note, however, that this depends on the success of energy efficiency policies such as appliance standards and upgrades to gas boilers due to building regulations. The Government's conclusions also partly depend on assumptions about the future trajectory of gas prices. If prices are lower than the Government expects, low carbon policies would be more likely to put upward pressure on bills.

219. There will be costs, we were told, associated with maintaining resilience as the reliance on intermittent renewables increases. **The extent of the costs of maintaining resilience as the reliance on intermittent renewables**

273 Written evidence from Ofgem (REI0044)

274 The policies listed as having an effect are: Small-scale Feed In Tariff support cost, Electricity Market Reform support cost, Renewables Obligation support cost, EU Emissions Trading Scheme and Carbon Price Floor carbon price impact, Warm Home Discount support cost, Energy Companies Obligation support cost and Green Deal admin cost.

275 DECC, *Estimated impacts of Energy and Climate Change Policies on Energy Prices and Bills* (March 2013): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/172923/130326_-_Price_and_Bill_Impacts_Report_Final.pdf. [accessed February 2015]

276 DECC, *Supplementary Tables: Estimated impacts of energy and climate change policies on energy prices and bills.* (November 2014): https://www.gov.uk/government/publications/estimated-impacts-of-energy-and-climate-change-policies-on-energy-prices-and-bills-2014 [accessed February 2015]

increases, however, was vigorously debated during our inquiry. We found that it was difficult to understand the different methodologies used, compare figures and reach firm conclusions.

220. For example, Matthew Bell, Chief Executive Officer, Committee on Climate Change (CCC), told us that:

> "We did a piece of work, which is public so we can certainly share it, in about 2011 that looked at the cost of intermittency, and that estimated that it would add about 1p per kilowatt hour to build the more resilient network that was needed, with the evidence that we had at that point in time. To give you a sense of 1p per kilowatt hour, we are currently delivering energy to households at about 15p per kilowatt hour. That gives you an order of magnitude feel, but there is lots of uncertainty, as we have emphasised, around all these things."[277]

221. The Scientific Alliance, however, claimed much higher costs (looking to 2020):

> "We estimate the additional cost in 2020 with the renewable programme would amount to some £12.3 billion, equivalent to £165 or 25% on the average domestic consumer's bill."[278]

222. We heard from Professor Green, Professor of Sustainable Energy Business, Imperial College London, and Professor Hughes, Professor of Economics, University of Edinburgh, who disagreed with each other on the costs of decarbonising the electricity system using renewables. They had markedly different views about the costs of integrating renewables into the electricity system in future.[279]

223. Dr Gross, Reader in Energy Policy and Technology, Imperial College London, argued that the costs of intermittency were likely to be 1p to 2p per kilowatt hour:

> "We have the grid upgrading costed by the electricity network and supply group at about £9 billion. If you annualise that and smear it out across consumers, and take into account the additional system balancing services that are likely to be required to manage wind and the impact on capacity and so on, and if you work through all that, with about 20% or so penetration of renewables on the system you come to a small number of perhaps 1p to 2p per kilowatt hour. The problems begin to arise when we start to look at very ambitious post-2030 combinations of very deep penetrations of renewables, with perhaps lots of solar on the distribution network and perhaps new nuclear stations as well."[280]

224. Dr Constable, Director, Renewable Energy Foundation, argued that: "1p to 2p per kilowatt hour might sound small, but you must remember that the UK

277 Q 137 (Matthew Bell)

278 Written evidence from the Scientific Alliance (REI0046)

279 Written evidence from Professor Gordon Hughes (REI0049); Supplementary written evidence from Professor Richard Green (REI0050)

280 Q 174 (Dr Robert Gross)

consumes 330 terawatt hours per year, so it is not a small number when you multiply it."[281]

225. While we received conflicting evidence on costs, we also heard that it may be the case that renewables are not as inflexible as is generally held:

> "National Grid and the wind industry are working together to develop the provision of ancillary services, such as frequency response, from wind generators to the System Operator (SO), such that there is no need for the SO to rely on thermal plant for these services … National Grid is also developing a mechanism for provision of a "rapid frequency response" service, whereby highly flexible wind generation can act rapidly to respond to any system disturbances, in view of reductions in the inertia of the system as a whole."[282]

226. As set out in preceding chapters, demand side response, interconnection and storage all provide ways of dealing with intermittency at the same time as improving the resilience of the electricity system. An additional way of balancing the system is to use flexible generation, and one such option is to continue to rely on fossil fuel plant for flexible generation. The output from fossil fuel plant can be varied more easily than that from current renewables. It is generally more expensive, however, to deliver variable, rather than constant, output from fossil fuel plant. Technologies are being developed, however, which will enable increased flexibility:

> "Some generation technologies already exist, or are in development, to help maintain resilience against intermittent generation. For example, some manufacturers are designing turbines that will be able to run flexibly in future, such as GE's FlexEfficiency 50 CCGT [Combined Cycle Gas Turbine] designed specifically for variable loads and operating conditions. When commercially proven and available, such designs will allow gas generation to respond to more volatile demand and intermittent supply in power markets."[283]

227. Set against this potential innovation in gas generation, however, is uncertainty about building gas plant. Professor Gibbins, University of Edinburgh, explained:

> "I am dealing with utility companies that are considering building gas plants, unabated and with carbon capture and storage. What they say is, "We really do not know how much we will be able to run in five or 10 years' time because it is going to be governed by how much wind is subsidised or incentivised on to the market". There is a great deal of uncertainty there when you are building conventional plant."[284]

Carbon Capture and Storage (CCS)

228. Continuing to use fossil fuel plant to provide flexible generation is not compatible with the UK's commitment, under the Climate Change Act 2008, to reduce greenhouse gas emissions by 80% by 2050. One way of maintaining

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281 Q 174 (Dr John Constable)

282 Written evidence from RenewableUK (REI0039)

283 Written evidence from GDF SUEZ Energy UK-Turkey (REI0036)

284 Q 92 (Professor Jon Gibbins)

flexible generation whilst reducing greenhouse gas emissions is to make use of carbon capture and storage (CCS) coupled to fossil fuel plant.

Box 9: Carbon Capture and Storage (CCS) [285]

CCS is the process of capturing CO_2 from generating plant, transporting it to a storage site and storing it such that it does not enter the atmosphere. This is normally done by depositing the CO_2 in an underground geological formation. CCS is a three stage process: capture, transportation and storage. Although these are not new technologies, there have been very few full scale projects that use all three together at commercial scale. Two commercial scale projects are now under active development in the UK, supported by the Government.[286] These projects are designed to undertake "detailed engineering, planning and financial work to finalise and de-risk aspects of the proposal ahead of taking final investment decisions, and proceeding to construction."[287] CCS needs to be proven at commercial scale but could have a significant effect on the use of fossil fuels in a low carbon future. The UK Government stated its ambitions to be a world leader in CCS, but planned projects were delayed and now the UK is only once again beginning to pilot CCS projects.

229. CCS has the potential to reduce the costs of decarbonising electricity generation:

> "CCS is an innovative technology which will help with the resilience of the system. Whilst addressing greenhouse gas emissions it will also enable fossil fuels to continue to be used as part of a low carbon generation mix and serve as an aid to balance variable forms of low carbon generation. CCS uses established technology in an innovative way to capture, transport and permanently store CO_2 emissions from fossil fuel power stations and industrial emitters beneath the sea bed. Flexible power generation with CCS enables the maximum levels of renewable and nuclear energy in the lowest cost way, with lowest emissions."[288]

230. Professor Gibbins argued that CCS was important in order to keep down the costs of decarbonisation, a view that was echoed by National Grid, the Energy Technologies Institute (ETI) and the Carbon Capture and Storage Association:

> "ETI's prediction is that by 2030, if you did not use CCS and you did it all [i.e. tried to meet greenhouse gas emission targets] with renewables,

285 In our 2014 report, Science and Technology Committee, *Waste or resource? Stimulating a bioeconomy* (3rd Report, Session 2013–14, HL Paper 141) we noted that waste gases from industry represented potentially important feedstocks for a bioeconomy and that carbon dioxide could be transformed into valuable products using emerging technologies. This raises the possibility, we noted, of moving from carbon capture and storage to carbon capture and reuse (paras 35–39).

286 These are the White Rose CCS Project at the Drax site in North Yorkshire and the Peterhead CCS Project in Aberdeenshire.

287 DECC, 'UK carbon capture and storage: government funding and support': https://www.gov.uk/uk-carbon-capture-and-storage-government-funding-and-support#ccs-commercialisation-competition [accessed February 2015]

288 Written evidence from National Grid (REI0017)

> you would be costing maybe of the order of £10 billion extra a year to the economy, and that would increase into several tens of billions by 2050."[289]

> "Analysis also shows that annual household energy bills could be £82 lower by 2030 with CCS in the energy mix than without."[290]

> "… if you elect not to use CCS, and therefore essentially do not use fossil fuels out to 2050 in terms of power generation, the first question is: can you still meet climate change targets? Our analysis says you can. So you can do without fossil fuels, but only at a cost. The cost is of the order of 1% or more of GDP. That one decision is the single biggest decision you make about the UK energy system in terms of the cost of the system and that gets passed on to consumers."[291]

> "Energy system modelling clearly demonstrates that the most affordable route to decarbonisation of the economy is through the deployment of CCS alongside the widespread deployment of renewable and nuclear. Modelling scenarios which remove CCS technologies demonstrate very considerable increases in the cost of decarbonisation. For example, the IPCC assessed a number of models and found that the increase in mitigation costs in scenarios with no CCS averaged 138%."[292]

231. CCS is very much an emerging technology and its commercial feasibility is still to be proven. Therefore, the argument that its widespread deployment will lower the costs of decarbonisation depends on the commercialisation of the technology and significant cost reductions being achieved over time. The world's first commercially operating coal-fired power plant which both captures and stores carbon is now in operation at Boundary Dam power station, Saskatchewan, Canada. This plant allows the production of 110 megawatts (MW) of power, which is still small scale, providing only enough electricity to power around 100,000 homes.[293]

232. An important step forward in enabling the commercialisation of CCS in the UK was taken in 2012 when the Government opened a UK Carbon Capture and Storage Commercialisation Competition.[294] This competition made £1 billion of capital funding available. The White Rose and Peterhead projects were named as the preferred bidders in March 2013. Whilst this funding is welcome, there have been delays in commissioning this work. Further CCS projects will also be needed. Dr David Clarke, CEO, Energy Technologies Institute (ETI), told us:

> "You need to continue with the current commercialisation projects that DECC are doing, which are absolutely critical, and you need to get probably between two and five full-scale plants up and running by the

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289 Q 94

290 Written evidence from National Grid (REI0017)

291 Q 134 (Dr David Clarke)

292 Written evidence from the Carbon Capture and Storage Association (CCSA) (REI0042)

293 Saskpower CCS, 'Boundary Dam Carbon Capture Project': http://saskpowerccs.com/ccs-projects/boundary-dam-carbon-capture-project/ [accessed February 2015]

294 The awarding of these contracts is as result of the second launch of the competition in 2012. The competition was first launched in 2006, but closed in 2011, having failed to award a contract.

mid-2020s, certainly by 2030, so that the investment community can see the viability or not of those systems."[295]

233. The Carbon Capture and Storage Association reinforced this argument:

"In addition to delivering the first projects the [Government's] policies must provide enough confidence to prospective developers on the future market for CCS that investment in a second phase of CCS projects can commence in parallel to the development of the competition projects. Bringing forward this second phase is key to supporting the progressive, cost-effective, roll-out of CCS that is necessary to delivering the benefits of this technology to the UK."[296]

234. Action will be needed to be taken to support further projects if the UK is to reap the full benefits from this technology. In addition to demonstration projects, it was put to us that the Government could also take further steps to ensure that market conditions favour the development of CCS. This would include establishing how the Contracts for Difference framework will apply to CCS:

"The EMR framework is not complete and this Government has still not established a CCS CfD, a CfD allocation framework for CCS or provided any clarity on the timing and volume of additional CCS projects that might be deployed. Until this work is completed the UK's CCS potential will not be realised." [297]

235. We note that this lack of clarity is likely to impact negatively on industry investment in CCS. An effective carbon price could also help to support the development of CCS. The cost-benefit of retrofitting CCS to existing plant is strongly influenced by the remaining life span of the plant. Although CCS may not as yet be a commercially viable option, building new plant in a way which would allow retro-fitting at a later stage could bring benefits.

Nuclear

236. Historically, in the UK, nuclear power has been used to provide a constant base load, rather than to respond flexibly to peaks in demand. Although nuclear power is likely to remain best suited to providing base load, new nuclear power plant have the potential to provide greater flexibility.

Box 10: Flexible Nuclear

How flexible is nuclear currently?

Nuclear power stations have low marginal costs, which means it is economically favourable to run them at high load factors. Consequently, the UK has traditionally used nuclear generation only for base load provision. This does not reflect any inherent limitation in the technology. It reflects that the current fleet of fossil-fuelled generation is better suited to load following. Modern nuclear plant are capable of providing some flexibility

295 Q 134 (Dr David Clarke)

296 Written evidence from the Carbon Capture and Storage Association (CCSA) (REI0042)

297 *Ibid.*

but currently only one plant, Sizewell B, provides automatic frequency response to help maintain grid stability.[298]

How flexible might nuclear be in the future?

As we transition to a low carbon system, intermittency from an increased share of renewables, such as wind, will likely create larger peaks and troughs in electricity generation. Low carbon, flexible backup generation will therefore play an important role in ensuring security of supply. If nuclear comprises a large share of this, it will need to load follow. Nuclear plant load-following already occurs in France today. Next generation nuclear plant can provide better flexibility than the current UK fleet. However, it has been argued that in the UK "nuclear power has been, and is likely to remain, a base-load technology for economic reasons."[299] National Grid "encourage all new generation, including new nuclear plant, to be flexible around the way in which it operates and to be capable of providing response services."[300] New emerging technologies could provide improved flexible nuclear generation:

- **Small Modular Reactors (SMRs)**. These are small[301] reactors that could be manufactured at a central factory and brought to the site fully constructed (i.e. modular). Many SMRs could be installed at one power station. It is argued that benefits of this type of nuclear generation could be: lower capital investment; less on-site construction, and hence faster construction times; greater siting flexibility; and enhanced safety and security. However, the relatively small power output of SMRs is likely to result in higher generation costs than traditional large nuclear generation. The Energy Technologies Institute (ETI) states that SMRs will provide "more agile and flexible electricity output than large nuclear plant" and see a potential role for SMRs "in concurrent deployment alongside large base-load [nuclear generation]".[302]
- **Molten Salt Reactors (MSRs)**. These are reactors in which the primary coolant, or even the fuel itself, is a molten salt mixture. Moltex Energy LLP asserts that their design, the Simple Molten Salt Reactor, offers enhanced safety features over standard nuclear generation techniques by eliminating runaway chain reactions and explosive leaks, and vastly reducing volatile fission products.[303] The Alvin Weinberg Foundation argues that "the MSR has outstanding load-following capability and will provide a low-carbon alternative to gas as a flexible source of electricity to support renewables." Furthermore, they assert that MSRs have "far greater load-following capability than solid-fuelled [nuclear] reactors".[304] Both Moltex Energy LLP and The Alvin Weinberg Foundation believe that MSRs can deliver relatively cheap and safe load-following capabilities to compete with gas generation.

298 Written evidence from the Scientific Alliance (REI0046)

299 Lauren Pouret, Nigel Buttery and William Nuttall, 'Is Nuclear Power Inflexible?' *Nuclear Future*, vol. 05, no. 6, (2009): http://www.nuclearinst.com/CoreCode/Admin/ContentManagement/MediaHub/Assets/FileDownload.ashx?fid=74608&pid=13034&loc=en-GB&fd=False [accessed February 2015]

300 Written evidence from National Grid (REI0017)

301 Typically less than 300 MW capacity.

302 Written evidence from the Energy Technologies Institute (REI0018)

303 Written evidence from the Moltex Energy LLP (REI0009)

304 Written evidence from the Alvin Weinberg Foundation (REI0027)

237. Indeed, nuclear power plant are already used flexibly in France, as they contribute a very high percentage of the nation's electricity generation. The Nuclear Industry Association explained:

> "Nuclear stations with their low variable costs, high availability and low carbon emissions are best suited to meet baseload demand, and this is how they have been operated, and are planned to operate, in the UK. However whilst this is the most economic course modern plant can be designed to be capable of load following and in France, which has a very large proportion of nuclear power on the system with hydro-electric power providing some flexibility to respond to changing demand, a number of the operating PWRs are able to change their output quickly at the request of the system operator.
>
> If the UK nuclear fleet were ultimately to make up a much bigger proportion of total generation it would be technically possible to provide nuclear plant capable of load-following too, although this would not be the optimum from an economic perspective."[305]

238. Professor Nuttall, Professor of Energy, Open University, was circumspect as to the prospects of British nuclear power stations operating flexibly:

> "… future British nuclear power stations could be operated flexibly but it makes little economic sense to do so … Looking, by the way, at the plants we already have in Britain, frankly, there is little prospect of operating the ageing advanced gas-cooled reactors flexibly. Although load-following, interestingly, could be technically possible, it is never going to happen from the AGRs, I would say. The interesting one that we have already is Sizewell B pressurised water reactor, which could be deployed for load-following and frequency response but there are no economic incentives to do that."[306]

239. The Scientific Alliance told us that some existing nuclear power stations could provide some flexibility:

> "Nuclear generation in the UK has traditionally been used only for base load provision. However, this is not because of any inherent limitation of the technology, but more an optimisation of the costs of generation. In France, the high proportion of nuclear generation on their grid system has required a flexible response to demand changes in order to contribute to system stability. Nevertheless some existing nuclear plants in the UK can provide some flexibility, being able to reduce load by a limited amount over a prescribed period. Five out of eight UK stations already offer this for grid system faults during grid outages and one can also provide automatic frequency response as a contribution to grid stability."[307]

240. Future nuclear technology could, however, offer increasing flexibility, the Scientific Alliance argued:

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305 Written evidence from the Nuclear Industry Association (REI0020)

306 Q 99 (Professor William Nuttall)

307 Written evidence from the Scientific Alliance (REI0046)

> "Developments in new nuclear reactors will include greater flexibility to respond to demand changes and to contribute to grid system stability, although it should be recognised that because of the low marginal cost of nuclear this will be a costly exercise compared with using fossil fuel generators in this role and is likely to be a last resort in the face of increasing penetration of wind and solar generation. The flexibility and grid stability contribution from nuclear generators will depend to some extent on design choice but there is no reason to limit the amount of new nuclear generation on this account."[308]

241. Professor Nuttall asserted that nuclear power innovation harboured potential for providing enhanced flexibility:

> "… the fluoride salt-cooled high-temperature reactor … aims to maximise system flexibility and, therefore, increase revenues by 50% compared to a conventional base-load nuclear power station. Their FHR concept incorporates natural gas combustion with nuclear preheating, high-temperature thermal storage, electricity to stored heat conversion, and process heat services such as industrial or metropolitan steam supply. Interestingly, their focus has not been to reduce nuclear costs—the premise of your question—but rather to maximise revenues in liberalised markets with high proportions of intermittent renewables. I think that nuclear power innovation is going to be part of our future and there is some opportunity in terms of new technologies."[309]

242. The Energy Technologies Institute contended that without new nuclear build, climate change targets would be harder to meet:

> "Without investment in a major new nuclear build programme, the cost and difficulty of meeting the UK climate change targets will rise very significantly. We consider that Small Modular Reactors (SMRs) may have a potential role in the UK future energy system in concurrent deployment alongside large base-load Generation III+ designs. SMRs would offer the additional potential to energise major heat networks through waste heat recovery, and provide electrical network balancing through provision of more agile and flexible electricity output than large nuclear plant."[310]

243. We have been concerned about planning for the UK's nuclear future for many years. Most recently, we conducted a major inquiry into nuclear research and development capabilities in 2011, which we continue to follow up.[311] We remain convinced that nuclear remains an integral part of the UK's energy mix, and that nuclear innovation offers significant potential. In this regard, we were disappointed to learn from Dame Sue Ion, Chair of the Nuclear Innovation and Research Advisory Board (NIRAB), that the Chancellor had been unable to include any provision for the nuclear R&D programme recommended by NIRAB in his Autumn Statement (2014). Dame Sue Ion

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308 Written evidence from the Scientific Alliance (REI0046)

309 Q 99 (Professor William Nuttall)

310 Written evidence from the Energy Technologies Institute (REI0018)

311 Science and Technology Committee, *Nuclear research and development capabilities* (3rd Report, Session 2010–12, HL Paper 221)

told us that she hoped that a positive outcome could be secured at the next Comprehensive Spending Review (CSR).[312]

244. **There is much debate around the costs of renewables and the costs of maintaining a resilient system that incorporates intermittent renewables. We recommend that the Government publishes a systematic review of the evidence available on the predicted costs of integration to 2030 and beyond, taking into account a wide range of scenarios. Allied to this, the Government should also disseminate more comprehensive evidence on the potential costs of low carbon generation and improve communication with the public on the costs and benefits. This would help to bring more clarity to the current debate.**

245. **Flexible generation will be increasingly important to balance the electricity system. The Government should ensure that incentives are in place so that all new generation is built in such a way as to maximise its flexibility, whilst ensuring that the costs to consumers are minimised. In addition, the Government should, with some urgency, clarify how Contracts for Difference will apply to Carbon Capture and Storage.**

246. **Funding for nuclear research and development is vital if the UK is to achieve the objectives set out in the Nuclear Industrial Strategy and begin to re-establish itself at the forefront of nuclear innovation. We recommend that the next Comprehensive Spending Review makes financial provision for the nuclear R&D programme recommended by NIRAB.**

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[312] Letter from Dame Sue Ion, Chair, Nuclear Innovation and Research Advisory Board, 16 January 2015. Available online: http://www.parliament.uk/documents/lords-committees/science-technology/Nuclearfollowup/20150116-Dame-Sue-Ion-NIRAB.pdf

CHAPTER 9: DIRECTING THE FUTURE

Research, development and demonstration (RD&D)

247. It is certain that new technologies will play a large part in providing a resilient electricity system in the future. As is evident from previous chapters, the speed of technological change is often rapid and the electricity system is constantly changing as a result. It is important to note, however, that technology alone will not provide a resilient electricity system. The ways in which people make use of technology, and the market and organisational structures which are put in place, will be of equal importance.

248. Future resilience will not depend on the implementation of a single technology. Current technological solutions, such as gas, wind and solar, may be displaced as more advanced technologies are developed. This chapter discusses the need for research and development (R&D), as well as for demonstration and deployment, of a wide range of technologies. Only in this way can we be confident that the most cost effective solutions are discovered and exploited.

249. Unfortunately there are not limitless funds available to invest in the development of new technologies. In a resource constrained environment, there will always be arguments about how best to invest the funding available. This provoked much debate during the course of our inquiry.

250. One question is around the balance of investment in early stage research versus the later stages of development, demonstration and deployment. These different stages are sometimes referred to as 'technology readiness levels.' The UK is typically seen as strong in the early stages of R&D, but weaker at the later stages, which are necessary to bring a product to market. The gap which exists between R&D and commercial deployment is often referred to as the 'valley of death.'

251. Another question is whether specific areas of research, development, demonstration and deployment should receive priority over others. In the absence of limitless funding some degree of prioritisation will no doubt be necessary. During our inquiry, however, some cautioned against the Government 'picking winners.'[313]

252. A wide range of technologies is likely to be needed to ensure that the future electricity system is resilient, affordable and sustainable and it is not possible to be confident about which areas of research and development will yield successful outcomes. As Professor Dieter Helm from the University of Oxford put it, in research: "You need to let quite a lot of flowers bloom."[314] Dr David Clarke from the Energy Technologies Institute commented: "if you put me on the spot and said, 'What will it [the electricity system] look like in 2050?' whatever answer I give you will be wrong. Uncertainty and statistics say it will be wrong."[315] Matthew Bell from the Committee on Climate Change told us:

313 QQ 47–48 (Professor Dieter Helm); Written evidence from BDO LLP (REI0011); Written evidence from GDF SUEZ Energy UK-Turkey (REI0036)

314 Q 51

315 Q 127 (Dr David Clarke)

> "Right now we do not know what technology mix will be the best technology mix and what demand-side response will be the best demand-side response to get us to where we need to be, and that is why it is sensible to be looking at and trialling and piloting a range of different technologies and a range of different measures. We will see which ones emerge as the most cost-effective ones …"[316]

253. Professor Dieter Helm disagreed with the Government's current approach to balancing investment between R&D and deployment. He argued that at present renewables do not provide a cost effective solution to tackling climate change and new technologies would therefore be needed.[317] His view was that the balance of funding is currently skewed, with too much spent on subsidising current renewables and not enough is spent on R&D: "I think it should be a much bigger pot [spent on R&D] relative to spending on existing technologies and subsidising those."[318]

254. Other witnesses, however, emphasised the importance of demonstration and deployment to support technologies in the early stages of their development, and to provide an incentive for innovation and cost reduction:

> "I completely disagree with the notion that we could abandon deployment of low-carbon technologies now and put money into R&D instead and that some sort of magic solution will pop out at some point in the future. It is like believing in the R&D fairy. It flies in the face of everything that we know about technological change and it completely fails to engage with the amount of time that it takes to roll out large amounts of new infrastructure. This is an urgent problem, which we need to get on with. We will obviously discover better ways of doing things in 30 years' time. To the extent that we can, we need to try to strike the right balance. I have read the transcript and I think that Dieter [Helm] was actually questioning whether we are striking the right balance. That is a very legitimate question, which we could explore more if we were not about to run out of time. To be absolutely clear, if you do not deploy anything, you do not get anywhere. You cannot build an offshore wind farm in the lab, you cannot build a PV factory in the lab and you cannot build a CCS pipeline in the lab. There are no magic solutions hiding—at least, not ones that will make a difference in the next 20 years or so." [319]

255. We support this view that demonstration and early deployment can contribute to bringing costs down. It could be argued that current 'subsidies' for low carbon technologies, such as Contracts for Difference (CfD), are in effect a way of supporting such demonstration and early deployment, but only if they are effective in the medium term in reducing the costs of these technologies. Excessive levels of subsidy can have the effect of artificially inflating costs.

256. As described in Chapter 1 of this report, Contracts for Difference offer different levels of support for different types of renewable technology. The idea is to offer greater levels of support for technologies which are at earlier stages

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316 Q 137 (Matthew Bell)

317 QQ 51–52 (Professor Dieter Helm)

318 Q 51 (Professor Dieter Helm)

319 Q 175 (Dr Robert Gross)

of development. Whilst some welcome the support provided through CfDs, others are critical of this approach, accusing the Government of 'picking winners'[320]. The Government itself states that its aim, however, is to move to a technology neutral approach.[321] An effective carbon price would help to support this.[322]

257. Although the above paragraphs focus mainly on electricity generation technologies, research, development and demonstration (RD&D) in demand side technologies (including storage) and for networks is of equal importance. The mechanisms for supporting RD&D in these areas are quite distinct. Generation and demand side technologies are much more diffuse and diverse, whereas for networks there is a 'natural monopoly' and a regulatory approach to stimulating innovation is possible.

258. To stimulate investment in RD&D by the network operators, Ofgem has two mechanisms in place: the Low Carbon Networks Fund (LCNF) and the RIIO (Revenue = Incentives + Innovation + Outputs) initiative. Ofgem explained that RIIO:

> "holds the network companies to account for delivering customer focused outputs in exchange for the revenue framework allowed. It also encourages innovation and a longer term focus in order to deliver sustained efficiencies and higher quality service. This includes new challenges, for example, from new technology generation."[323]

259. It appears, from the evidence we received, that these mechanisms have been successful in stimulating innovation. Energy UK commented that RIIO: "has already led to development of smart grid technology and research to reduce streetworks."[324] The Institution of Engineering and Technology (IET) were positive about the impact of the LCNF:

> "[The LCNF has] provided a strong incentive for transmission and distribution network operators to re-engage in effective research, development and deployment. All network operators have responded positively to the incentive and this has led to the development of many of […] technologies."[325]

260. Northern Powergrid told us about their Customer-Led Network Revolution project, co-funded by the LCNF, which:

> "… was one of the UK's largest smart grid projects looking at how distribution network operators can most efficiently facilitate the transition to a low carbon future. A key aspect related to the use of demand side response to address localised network constraints arising from the

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320 Written evidence from BDO LLP (REI0011); Written evidence from GDF Suez Energy UK-Turkey (REI0036)

321 Government (REI0040)

322 EDF Energy (REI0030); Energy UK (REI0034); Q 97 (Dr Keith Maclean)

323 Written evidence from Ofgem (REI0044)

324 Written evidence from Energy UK (REI0034)

325 Written evidence from the Institution of Engineering and Technology (IET) (REI0032)

projected increase in low carbon technologies connected to the network."[326]

261. Professor David Newbery from the University of Cambridge described the research results from the first four years of the LCNF as: "extraordinarily promising. From being probably one of the laggards in Europe in the smartening of the distribution network, we are probably now very much at the cutting edge."[327]

262. Others, however, had some reservations about RIIO and the LCNF. Whilst commending the research carried out by Network Operators in response to RIIO, the IET considered that: "there is much more to be done before we can be confident that we have the capability to effectively integrate these solutions at scale."[328] RenewableUK were positive about the effect of the LCNF, but considered that more was needed. They suggested that:

> "Rather than a call for innovation projects on any theme, we would like to see a strategy for innovation, with prioritised themes that require an answer by a particular time. This would make such innovation support more strategic and more effective in informing solutions to problems as these appear on the horizon."[329]

263. In the preceding chapters we describe the need for RD&D in electricity storage and nuclear energy. An additional area where research will be needed is in end-use energy demand. Organisations such as Sustainability First have undertaken large bodies of work in this area, in part funded by the LCNF.[330] Although we heard that much more needs to be done to understand demand, we note that the Research Councils are already investing in research in this area, for example through the DEMAND Centre:

> "The DEMAND Centre is one of six research centres funded by the Research Councils examining end-use energy demand from different perspectives. In total, the Centres represent a £43m investment aiming to ensure the UK is recognised as an international lead in this area of research."[331]

264. What is clear is that RD&D across the entire electricity system will be needed; in generation, networks, demand side technologies and in end-use energy demand. It is important to note that all these parts are interconnected in systems and there is a need for RD&D across the whole electricity system that tries out new ways of doing things.

265. The new Energy Systems Catapult may help to achieve this. The Catapult is due to launch in April 2015. As yet, the precise remit of the Catapult is unclear,

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326 Written evidence from Northern Powergrid (REI0059)

327 Q 75 (Professor David Newbery)

328 Written evidence from the Institution of Engineering and Technology (IET) (REI0032)

329 Written evidence from RenewableUK (REI0039)

330 Sustainability First, 'GB Electricity Demand Project': http://www.sustainabilityfirst.org.uk/gbelec.html [accessed February 2015]

331 Written evidence from the DEMAND Centre (REI0037)

but it is anticipated that, as with the other Catapult centres, it will engage with industry in the development and demonstration of innovative technologies:

> "… with Innovate UK we are setting up a body called the Energy Systems Catapult, and its business plan is to look at the system integration issues of the energy system. We have been having a discussion with the catapult, as part of writing that business plan, that there is a work stream there for them to do to become a technical centre to look at those types of issues."[332]

266. We welcome the establishment of the Energy Systems Catapult, although at present its exact remit is unclear. It will be important to see how the new Catapult works with, and hopefully complements, existing institutions with a whole systems remit, such as the Energy Technologies Institute (ETI) and the UK Energy Research Centre (UKERC). We look forward to hearing further details about the proposed functions of the Catapult.

267. It is our view that the Government should continue to support demonstration and early deployment so that new technologies do not fall down the well-publicised 'valley of death' between R&D and commercial deployment. No one technology will provide the answer and we call on the Government to continue to support research, development and demonstration and early deployment of a range of technologies. Although, in a funding constrained environment, some areas must be prioritised over others, it is important that the rationale for such decisions is transparent and evidence based. Finally the importance of international collaboration on RD&D should not be underestimated.

268. **We recommend that the Government supports research, development, demonstration and early deployment across a diverse range of technologies. This should include electricity supply, demand side response, storage and smarter networks. Particular attention should be paid to technologies that could strengthen electricity system resilience and how these technologies fit together in systems. Given budgetary constraints, there will be a need to prioritise some technologies over others. We recommend that the rationale for these choices is clear, transparent and made publicly available.**

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[332] Q 27 (Craig Lucas)

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

Chapter 2: The electricity system

1. **Given its policy objectives, we conclude that the Government has had little choice but to play a greater role in managing the electricity system. We therefore endorse the Government's adoption of a managed market and stress that it is explicitly for the Secretary of State to provide leadership and clarity on responsibilities across the sector. Balancing security of supply, sustainability and affordability (the trilemma) is a first order issue for the Secretary of State. We recommend that the Secretary of State clearly sets out the Government's approach to balancing the trilemma and is clear with Parliament and the public about the pressures which will accrue on affordability under the current state of technology.** (Paragraph 37)

2. **We conclude that it is imperative that the electricity system is viewed as a whole in order to enable effective engineering integration across the electricity system as changes occur. We look forward to analysis from the new Energy Systems Catapult—or another suitable organisation—about how effective decisions can be made in the context of the whole electricity system. This should include examining the thinking underpinning the Institution of Engineering and Technology's proposed 'system architect.' We look forward to receiving progress reports on the findings of this work.** (Paragraph 47)

Chapter 3: Will the lights go out?

3. **We conclude that because of the measures put in place by National Grid, the lights are unlikely to go out due to insufficient generation capacity.** (Paragraph 62)

4. **We conclude that successive governments should have anticipated the shrinking capacity margin earlier and taken steps to address it. As a result of inaction, the narrow capacity margin which emerged posed a threat to resilience. This has been mitigated using expensive measures with a heavy reliance on fossil fuel generation. This is not a good example of how the trilemma can be most effectively balanced. We recommend that the Government takes a more rigorous approach to long-term planning to avoid such situations arising in the future. Furthermore, we recommend that the Government reassesses whether it is procuring the right amount of capacity through the Capacity Market to offer an optimal cost-benefit balance to consumers.** (Paragraph 98)

5. **In order to make effective decisions on resilience, reliable information about the true costs of electricity shortfalls is needed. We are surprised to find a paucity of information in this area. We recommend that the Government funds further research into the costs of shortfalls and publishes its findings. This information should be used to determine whether the current Reliability Standard is appropriate for making decisions on the procurement of capacity.** (Paragraph 99)

6. **We recommend that the Government reviews the contribution interconnection and industrial backup generation could make to capacity margins. It is not currently clear how much industrial backup generation is potentially available. We recommend that the Government identifies and**

publishes information on the amount of industrial backup generation which could be made available. (Paragraph 100)

Chapter 4: Risks to resilience

7. In the event of power outages, it is essential that those consumers affected can access accurate and timely information about the developing situation. We note and commend the work underway to improve communications, including the provision by April 2016 of a single national emergency number for consumers to use to contact their Distribution Network Operator in the event of a power disruption. It is important that this deadline is met and that a comprehensive plan is developed for dissemination of the national emergency number, and Parliament will wish to be kept appraised regularly of progress. (Paragraph 109)

8. The risk of breaches to cyber security are real and will continue to evolve as the electricity system becomes ever more dependent on ICT. While we note that the Government is taking action in this area, we are concerned about the threat in the medium term as the electricity system becomes increasingly reliant on fast communication, on data, and dependent on automation. As new threats are identified so the Government must work ever more closely with stakeholders and provide appropriate funding for efforts to combat cyber-attack. The Government must ensure that cyber security factors are embedded at the earliest stages of electricity system design. (Paragraph 122)

9. We conclude that, as far as we are in a position to judge, the Government and relevant bodies have taken—and continue to take—steps to ensure resilience to threats, and that planning and emergency response procedures seem robust.(Paragraph 129)

10. We would urge the Government, however, to ensure that it:

    - engages actively with the science and engineering community in order to identify new and emerging threats to resilience; and
    - draws on the very best available evidence to enable timely and cost effective planning. (Paragraph 130)

11. In emergency planning, there is no substitute for conducting periodic simulations of emergency scenarios with Ministerial involvement. We therefore recommend that periodic simulations of emergency scenarios with Ministerial involvement continue to take place and that information about such exercises, is, as appropriate, reported to Parliament. (Paragraph 131)

Chapter 5: Changing demand

12. While it has not been a principal focus of our inquiry, we conclude that improving energy efficiency is of vital importance. For example, if heat pumps are to be effective, then having well insulated buildings will be critical. Effective retrofits, for instance, will reduce the amount of electricity needed for heat pumps, and will arguably help to reduce the stress on the electricity system in the future. It is essential for building regulations to ensure energy efficiency. (Paragraph 151)

13. Smart meters, produced with appropriate functionality, will be essential in facilitating greater use of Demand Side Response in homes. We recommend

that the Government ensures that no further delays occur in the roll out of smart meters and that Parliament is updated periodically about progress towards the 2020 target. Communicating the benefits of smart meters and incentivising consumers will be imperative and, to this end, we recommend that the Government, in partnership with industry, develops a comprehensive communications strategy with the aim of maximising the potential of smart meters. (Paragraph 170)

14. Demand Side Response (DSR) offers significant potential for balancing supply and demand. We recommend that the Government ensures that DSR is not disadvantaged in the Capacity Market relative to generation. To this end, we recommend that the length of DSR contracts in the Capacity Market should be brought into line with generation. (Paragraph 181)

15. We recommend that the Government conducts and publishes detailed assessments of what Demand Side Response (DSR) could potentially achieve. In addition, we recommend that the Government develops and publishes a plan, which includes specific targets, for the public sector to implement Demand Side Response measures and so set an example. (Paragraph 182)

Chapter 6: Interconnection

16. There is a worrying lack of clarity about what options exist if a number of interconnected countries experience system stress simultaneously. We recommend that the Government publishes an analysis of the effects of interconnectors on UK electricity resilience under a broad range of scenarios. This analysis should include an assessment of how interconnectors might be used at times when the system is under stress. It should specifically assess the case for restrictions / agreements to be put in place with other countries at times of system stress if there is evidence that resilience could be compromised. (Paragraph 200)

Chapter 7: Electricity storage

17. In addition to investing in Research & Development in electricity storage, the Government and Innovate UK should ensure that high potential demonstration projects are adequately funded. In addition, the Government should take steps to improve the market framework so as to stimulate investment in electricity storage. As a step towards improving the market framework, we recommend that the Government examines whether electricity storage should be placed under the Contracts for Difference regime rather than in the Capacity Market and reports its findings. (Paragraph 213)

Chapter 8: Flexible generation

18. The extent of the costs of maintaining resilience as the reliance on intermittent renewables increases, however, was vigorously debated during our inquiry. We found that it was difficult to understand the different methodologies used, compare figures and reach firm conclusions. (Paragraph 219)

19. There is much debate around the costs of renewables and the costs of maintaining a resilient system that incorporates intermittent renewables. We recommend that the Government publishes a systematic review of the evidence available on the predicted costs of integration to 2030 and beyond, taking into account a wide range of scenarios. Allied to this, the Government should also disseminate more comprehensive evidence on the potential costs

of low carbon generation and improve communication with the public on the costs and benefits. This would help to bring more clarity to the current debate. (Paragraph 244)

20. Flexible generation will be increasingly important to balance the electricity system. The Government should ensure that incentives are in place so that all new generation is built in such a way as to maximise its flexibility, whilst ensuring that the costs to consumers are minimised. In addition, the Government should, with some urgency, clarify how Contracts for Difference will apply to Carbon Capture and Storage. (Paragraph 245)

21. Funding for nuclear research and development is vital if the UK is to achieve the objectives set out in the Nuclear Industrial Strategy and begin to re-establish itself at the forefront of nuclear innovation. We recommend that the next Comprehensive Spending Review makes financial provision for the nuclear R&D programme recommended by NIRAB. (Paragraph 246)

Chapter 9: Directing the future

22. We recommend that the Government supports research, development, demonstration and early deployment across a diverse range of technologies. This should include electricity supply, demand side response, storage and smarter networks. Particular attention should be paid to technologies that could strengthen electricity system resilience and how these technologies fit together in systems. Given budgetary constraints, there will be a need to prioritise some technologies over others. We recommend that the rationale for these choices is clear, transparent and made publicly available. (Paragraph 268)

APPENDIX 1: LIST OF MEMBERS AND DECLARATIONS OF INTEREST

Members

Lord Broers (Co-opted)
Lord Dixon-Smith
Lord Hennessy of Nympsfield
Baroness Hilton of Eggardon
Baroness Manningham-Buller
Lord O'Neill of Clackmannan
Lord Patel
Lord Peston
Lord Rees of Ludlow
Viscount Ridley
Earl of Selborne (Chairman)
Baroness Sharp of Guildford
Lord Wade of Chorlton
Lord Willis of Knaresborough
Lord Winston

Declarations of interest

Lord Broers
Fellow, Royal Academy of Engineering
Fellow, Royal Society
Fellow, Institution of Engineering and Technology
Lord Dixon-Smith
No relevant interests declared
Baroness Hilton of Eggardon
No relevant interests declared
Lord Hennessy of Nympsfield
Fellow, the British Academy
Baroness Manningham-Buller
Chair, Council of Imperial College London
Lord O'Neill of Clackmannan
Adviser to Electrical Contractors Association
Chairman of both Scottish Power and National Grid Stakeholder Advisory Panels
Lord Patel
No relevant interests declared
Lord Peston
No relevant interests declared
Lord Rees of Ludlow
Fellow, Royal Society
Shares in Centrica
Shares in British Gas
Viscount Ridley
Income from coal mining on family-owned land
Income from a wind turbine
Shares in Rio Tinto plc
Shares in National Grid

Earl of Selborne

Hon. Fellow, Institution of Engineering and Technology
Fellow, Royal Society
Chairman, Foundation for Science and Technology
Shares in Rio Tinto plc
Shares in SSE plc

Baroness Sharp of Guildford

Former Senior Fellow of Science Policy Research Unit, University of Sussex
Patron, Campaign for Science and Engineering

Lord Wade of Chorlton

Director of MITON Group plc (fund management)

Lord Willis of Knaresborough

No relevant interests declared

Lord Winston

Academic at Imperial College London (Professor of Science and Society)
Hon. Fellow, Royal Academy of Engineering

A full list of Members' interests can be found in the Register of Lords Interests: http://www.parliament.uk/mps-lords-and-offices/standards-and-interests/register-of-lords-interests

Specialist Adviser

Professor Jim Watson

Personal Interests (those that provide direct funding and other roles in which he acts in a personal capacity)

Council Member, British Institute for Energy Economics
Trustee, Chesshire Lehmann Fund
Advisory Board member, Carbon Connect
Panel member, South African Academy of Sciences commission on green technology
Member of Local Authority Selection Panel for Energy Technologies Institute Smart Systems and Heat Programme
Member of DECC and Defra social science expert panel
Advisory Board member, Low Carbon Research Institute (Wales)
Steering Group member, WholeSEM energy systems modelling research consortium
Advisory Board member, ESRC network plus on the social science of the nexus
Independent Advisory Panel member, UK CCS Research Centre
Occasional advisor & reviewer for IPPR, Green Alliance, WWF and other organisations
Member of mid term evaluation panel, energy social science research centres, Research Council of Norway
Consultant, with UKERC colleagues at University of Strathclyde, China Light and Power

Non Personal Interests (those that provide funding to his research group, centre or department)

UK Energy Research Centre (phase 3: May 2014–April 2019)
Infrastructure Transitions Research Consortium (2011–2015)
E.On UK co-funded PhD studentship
European Climate Foundation
Energy Technologies Institute

APPENDIX 2: LIST OF WITNESSES

Evidence is published online at http://www.parliament.uk/resilience-of-electricity-infrastructure and available for inspection at the Parliamentary Archives (020 7219 3074).

Evidence received by the Committee is listed below in chronological order of oral evidence session and in alphabetical order. Those witnesses marked with ** gave both oral evidence and written evidence. Those marked with * gave oral evidence and did not submit any written evidence. All other witnesses submitted written evidence only.

Oral evidence in chronological order

**	Dr Simon Harrison, Chair of the Energy Policy Panel, Institution of Engineering and Technology (IET)	QQ 1–16
*	Professor John Loughhead, representing the Royal Academy of Engineering	
**	Sarah Rhodes, Head of Energy Resilience, Department of Energy and Climate Change (DECC)	QQ 17–28
**	Craig Lucas, Head of Engineering, Department of Energy and Climate Change (DECC)	
**	Andy Shields, Head of Security of Electricity Supply, Department of Energy and Climate Change (DECC)	
*	Guy Newey, Head of Policy, OVO Energy	QQ 29–43
*	Dr Laurence Barrett, Strategy Project Manager, E.ON UK	
**	Paul Spence, Director of Strategy and Corporate Affairs, EDF Energy	
*	Professor Dieter Helm CBE, University of Oxford	QQ 44–52
**	Mike Calviou, Director of Transmission Network Service, National Grid	QQ 53–68
**	Tony Glover, Director of Policy, Energy Networks Association (ENA)	
**	Professor Keith Bell, University of Strathclyde, representing the UK Energy Research Centre (UKERC)	QQ 69–79
**	Professor David Newbery, Director of the Energy Policy Research Group (EPRG), University of Cambridge, Research Fellow at Imperial College London	
**	Professor Michael Grubb, University College London	
*	Dr Nina Skorupska, Chief Executive Officer, Renewable Energy Association	QQ 80–90
**	Professor Richard Green, Imperial College London	

**	Professor Gordon Hughes, University of Edinburgh	
*	Professor Jon Gibbins, University of Edinburgh	QQ 91–101
*	Dr Keith MacLean, University of Exeter	
*	Professor William Nuttall, Open University	
**	Anthony Price, Director, Electricity Storage Network	QQ 102–113
**	Dr Charlotte Ramsay, Project Director for NSN Link, National Grid	
*	Professor Goran Strbac, Imperial College London	
**	Professor Gordon Walker, Co-Director, the DEMAND Centre	QQ 114–123
*	Dr Howard Porter, Chief Executive Officer, BEAMA	
**	Michael Ware, Partner for New Energy and Environment, BDO LLP	
*	Matthew Bell, Chief Executive Officer, Committee on Climate Change (CCC)	QQ 124–138
**	Dr David Clarke, Chief Executive Officer, Energy Technologies Institute (ETI)	
**	Professor Kevin Anderson, representing the Resilient Electricity Networks for Great Britain (RESNET) project, University of Manchester	
*	Professor Catherine Mitchell, University of Exeter	QQ 139–149
*	Dr Konstantin Staschus, Secretary-General, European Network of Transmission System Operators for Electricity	
*	Dr John Roberts, CBE, FREng, representing the Royal Academy of Engineering	QQ 150–166
*	Dr Robert Gross, Imperial College London	QQ 167–175
*	Rupert Darwall	
**	Dr John Constable, Director, Renewable Energy Foundation	
**	Rachel Fletcher, Senior Partner for Markets, Ofgem	QQ 176–185
**	Maxine Frerk, Senior Partner for Smarter Grids and Governance: Distribution, Ofgem	
**	Rt Hon Ed Davey MP, Secretary of State for Energy and Climate Change, Department of Energy and Climate Change (DECC)	QQ 186–198
**	Jonathan Mills, Director, Electricity Market Reform, Department of Energy and Climate Change (DECC)	

Alphabetical list of all witnesses

	The Alvin Weinberg Foundation	REI0027
	Aston University	REI0010
**	BDO LLP (QQ 114–123)	REI0011
*	BEAMA (QQ 114–123)	
	David L. Bowen	REI0001
	Stephen Browning	REI0007
	Carbon Capture and Storage Association (CCSA)	REI0042
	Dr Deeph Chana, Imperial College London	REI0051
	City of London Corporation	REI0029
*	Committee on Climate Change (CCC) (QQ 124–138)	
	Confederation of UK Coal Producers (CoalPro)	REI0021
*	Rupert Darwell (QQ 167–175)	
**	The DEMAND Centre, Lancaster University (QQ 114–123)	REI0037
**	Department for Energy and Climate Change (DECC) (QQ 17–28) (QQ 186–198)	REI0040
	Durham Energy Institute, Durham University	REI0016
*	E.ON UK (QQ 29–43)	
	E3C Electricity Task Group (ETG)	REI0033
**	EDF Energy (QQ 29–43)	REI0030 REI0053
**	The Electricity Storage Network (QQ 102–113)	REI0012
**	Energy Networks Association (ENA) (QQ 53–68)	REI0041
**	Energy Technologies Institute (ETI) (QQ 124–138)	REI0018
	Energy UK	REI0034
*	The European Network of Transmission System Operators for Electricity (QQ 139–149)	
	Professor David Fisk, Imperial College London	REI0051
	Flexitricity	REI0058
	GDF SUEZ Energy UK-Turkey	REI0036
*	Professor Jon Gibbins, University of Edinburgh (QQ 91–101)	
**	Professor Richard Green, Imperial College London (QQ 80–90)	REI0050 REI0056
*	Dr Robert Gross, Imperial College London (QQ 167–175)	
**	Professor Michael Grubb, University College London (QQ 69–79)	REI0026

*	Professor Dieter Helm CBE, University of Oxford (QQ 44–52)	
	Alex Henney, EEE Ltd	REI0015 REI0055
	Honeywell	REI0019
**	Professor Gordon Hughes, University of Edinburgh (QQ 80–90)	REI0049
	IESIS	REI0013
**	The Institution of Engineering and Technology (IET) (QQ 1–16)	REI0032 REI0052
	KiWi Power	REI0057
	Llinos Lanini	REI0005
*	Dr Keith MacLean, University of Exeter (QQ 91–101)	
*	Professor Catherine Mitchell, University of Exeter (QQ 139–149)	
	Moltex Energy LLP	REI0009
**	National Grid (QQ 53–68) (QQ 102–113)	REI0017 REI0060
**	Professor David Newbery, University of Cambridge (QQ 69–79)	REI0026
	Northern Powergrid	REI0059
	Nuclear Industry Association (NIA)	REI0020
*	Professor William Nuttall, Open University (QQ 91–101)	
**	Ofgem (QQ 176–185)	REI0044
	Harry Osborn	REI0035
*	OVO Energy (QQ 29–43)	
	PCAH (Parents Concerned about Hinkley)	REI0002
	Marco Pogliano	REI0008
*	Renewable Energy Association (QQ 80–90)	
**	Renewable Energy Foundation (QQ 167–175)	REI0054
	RenewableUK	REI0039
**	Resilient Electricity Networks for Great Britain (RESNET) project (QQ 124–138)	REI0025
*	Royal Academy of Engineering (QQ 1–16) (QQ 150–166)	
	The Royal Astronomical Society	REI0048
	RSA Group	REI0028
	The Scientific Alliance	REI0046
	Hugh Sharman	REI0006

	Barrie Skelcher	REI0003
	Dr Iain Staffell, Imperial College Business School	REI0056
	Storelectric Ltd	REI0004
*	Professor Goran Strbac, Imperial College London (QQ 102–113)	
**	UK Energy Research Centre (UKERC) (QQ 69–79)	REI0031
	UK Hydrogen and Fuel Cell Association	REI0023
	The Utility Regulator	REI0024

APPENDIX 3: CALL FOR EVIDENCE

21 July 2015

The House of Lords Science and Technology Select Committee, under the Chairmanship of Lord Selborne, is conducting an inquiry into *the resilience of electricity infrastructure*. This includes electricity generation, transmission and distribution infrastructure. The Committee invites interested individuals and organisations to submit evidence to this inquiry.

Background

Energy policy in the UK focusses on balancing three interconnected demands: energy security, affordability and decarbonisation. This is known as the energy trilemma. Within this framework, this inquiry looks specifically at the current and future contribution of science and technology to ensuring the resilience of the UK's electricity infrastructure.

In the short term the balance between supply and demand will be affected by the closure of aging power stations. On 30 June, the energy regulator, Ofgem,[333] published its latest assessment of Britain's capacity margins—the surplus of electricity generated relative to demand. Margins are expected to tighten over the next two winters, dropping to their lowest levels in 2015/16.[334] The narrowing of these margins has implications for the resilience of electricity systems.

Measures are being taken to improve Capacity Margins. As time is too short to replace this lost generation capacity by building new plant, the National Grid will procure new 'balancing services.'[335] These contracts for balancing services are with generating plant that would otherwise be closed or 'mothballed' or with large energy users who have the flexibility to reduce their demand at peak times. As a longer term solution the Government will put in place a Capacity Market, which will bring forward new power plants from 2018.[336]

In addition to these short term measures, large scale investment in new electricity infrastructure will be needed over the coming decades. As well as providing resilience, this infrastructure will need to deliver low carbon electricity at affordable prices.

The requirements for decarbonisation are set by the Climate Change Act 2008, which established legally binding targets for the reduction of greenhouse gas emissions by 80% by 2050.[337] The power sector accounts for around 27% of the UK's greenhouse gas emissions. The Committee on Climate Change therefore

333 Office of Gas and Electricity Markets

334 Ofgem, *Electricity Capacity Assessment Report 2014*. https://www.ofgem.gov.uk/ofgem-publications/88523/electricitycapacityassessment2014-fullreportfinalforpublication.pdf [accessed February 2015]

335 National Grid, 'National Grid to contract for new balancing services' (10 June 2014): http://www2.nationalgrid.com/Media/UK-Press-releases/2014/National-Grid-to-contract-for-new-balancing-services [accessed February 2015]

336 DECC, 'Electricity Market Reform': https://www.gov.uk/government/policies/maintaining-uk-energy-security--2/supporting-pages/electricity-market-reform [accessed February 2015]

337 80% of 1990 levels.

recommends that the carbon intensity of power generation should be reduced from 500 g CO_2/kWh to 50 g CO_2/kWh by 2030.[338]

Existing technologies provide three main ways of achieving decarbonisation of electricity generation: renewables, nuclear and using carbon capture and storage with fuel-burning generation. The Government aim to stimulate investment in these technologies by introducing Contracts for Difference, which offer fixed prices for low carbon electricity generation.

Renewables and nuclear generate a much less flexible supply of electricity than fuel-burning plant. Nuclear provides a constant base load, but generation cannot easily be increased in response to peaks in demand. Meanwhile, the amount of electricity generated by renewables varies depending on factors such as weather conditions.

There are existing and emerging technologies which can provide additional low carbon generation capacity at peak times or smooth out peaks of demand. In this inquiry we seek further information on the options for achieving this. This could include:

- electricity storage;
- increased interconnection to overseas electricity networks;
- dynamic management of demand;
- more flexible nuclear technology;
- flexible fuel burning generation coupled to carbon capture and storage (or use);
- flexible hydro generation;
- increasing the diversity of the renewable portfolio.

In addition, electricity infrastructure will face new challenges associated with more frequent extremes of weather. More localised electricity generation will place novel demands on the system. New demands for electricity supply, such as that from electric vehicles and heat pumps, will also have an impact. Meanwhile, energy efficiency measures can help to counter these increases in demand. Smart meters will be rolled out across the UK by 2020 and along with smart appliances will enable users to have increased control over their electricity use. As systems become increasingly complex they may also become more vulnerable to cyber-attack.

We invite evidence on the resilience of the UK's electricity infrastructure to peaks in demand and sudden shocks. We are interested in the resilience of the system both in the short term (to 2020) and in the medium term (to 2030) as electricity generation is decarbonised. In addition we could welcome evidence on the cost effectiveness of different approaches and the balance between achieving efficiency and sufficient redundancy to ensure a resilient system. We seek evidence on the impact and effectiveness of UK and EU policies, incentives and regulations in achieving this. The deadline for written evidence submissions is Friday, 19 September 2014.

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338 Committee on Climate Change, *Next steps on Electricity Market Reform: securing the benefits of low carbon investment (1 May 2013)*:. http://www.theccc.org.uk/wp-content/uploads/2013/05/1720_EMR_report_web.pdf [accessed February 2015]

Questions

If respondents consider that questions apply to both the short and medium term, please provide information on both, clearly stating the medium and long term issues. Respondents need not provide responses to all questions. Equally, if there are any crucial issues not captured under the questions we pose, please highlight what they are and explain their salience.

Short term (to 2020)

- How resilient is the UK's electricity system to peaks in consumer demand and sudden shocks? How well developed is the underpinning evidence base?
- What measures are being taken to improve the resilience of the UK's electricity system until 2020? Will this be sufficient to 'keep the lights on'?
- How are the costs and benefits of investing in electricity resilience assessed and how are decisions made?
- What steps need to be taken by 2020 to ensure that the UK's electricity system is resilient, affordable and on a trajectory to decarbonisation in the following decade? How effective will the Government's current policies be in achieving this?
- Will the next six years provide any insights which will help inform future decisions on investment in electricity infrastructure?

Medium term (to 2030)

- What will affect the resilience of the UK's electricity infrastructure in the 2020s? Will new risks to resilience emerge? How will factors such as intermittency and localised generation of electricity affect resilience?
- What does modelling tell us about how to achieve resilient, affordable and low carbon electricity infrastructure by 2030? How reliable are current models and what information is needed to improve models?
- What steps need to be taken to ensure that the UK's electricity system is resilient as well as competitively priced and decarbonised by 2030? How effective would current policies be in achieving this?
- Is the technology for achieving this market ready? How are further developments in science and technology expected to help reduce the cost of maintaining resilience, whilst addressing greenhouse gas emissions? Are there any game changing technologies which could have a revolutionary impact on electricity infrastructure and its resilience?
- Is UK industry in a position to lead in any, or all, technology areas, driving economic growth? Should the UK favour particular technology approaches to maintaining a resilient low carbon energy system?
- Are effective measures in place to enable Government and industry to learn from the outputs of current research and development and demonstration projects?
- Is the current regulatory and policy context in the UK enabling? Will a market-led approach be sufficient to deliver resilience or is greater coordination required and what form would this take?

APPENDIX 4: SEMINAR HELD AT THE HOUSE OF LORDS

14 October 2014

Members of the Committee present were Earl of Selborne (Chairman), Lord Broers (co-opted), Lord Dixon-Smith, Lord Hennessy of Nympsfield, Baroness Hilton of Eggardon, Baroness Manningham-Buller, Lord O'Neill of Clackmannan, Lord Patel, Lord Peston, Lord Rees of Ludlow, Viscount Ridley, Lord Wade of Chorlton, Lord Willis of Knaresborough and Lord Winston.

Presentations were heard from:

- Simon Skillings, Senior Associate, E3G;
- Paul Branston, Associate Partner, Costs and Outputs, and Emma Kelso, Partner, Wholesale Performance, Ofgem; and
- Judith Ward, Director, Sustainability First

APPENDIX 5: PRIVATE MEETING HELD AT THE HOUSE OF LORDS

25 November 2014

Members of the Committee present were Earl of Selborne (Chairman), Lord Broers (co-opted), Lord Dixon-Smith, Lord Hennessy of Nympsfield, Baroness Manningham-Buller, Lord O'Neill of Clackmannan, Lord Peston, Viscount Ridley, Baroness Sharp of Guildford, Lord Wade of Chorlton and Lord Winston.

At 10.40am Sarah Rhodes, Head of Energy Resilience, Department of Energy and Climate Change (DECC); Mark Prouse, Head of Security & Resilience Policy & Response, DECC; and Felicity Oswald-Nichols, Deputy Director, Risks, Infrastructure and High Impacts, Civil Contingencies Secretariat, Cabinet Office, assisted the Committee in its deliberations.

APPENDIX 6: ABBREVIATIONS AND ACRONYMS

CCC	Committee on Climate Change
CCGT	Combined Cycle Gas Turbine
CCS	Carbon Capture and Storage
CEGB	Central Electricity Generating Board
CfD	Contracts for Difference
CM	Capacity Market
CSR	Comprehensive Spending Review
DECC	Department of Energy and Climate Change
DEMAND	Dynamics of Energy Mobility and Demand
DNO	Distribution Network Operators
DSBR	Demand Side Balancing Reserve
DSR	Demand Side Response
E3C ETG	Energy Emergencies Executive Electricity Task Group
EMR	Electricity Market Reform
EPR	European Pressurised Reactors
ETI	Energy Technologies Institute
GW	Gigawatt (one billion watts)
GWh	Gigawatt hour
ICT	Information and Communications Technology
IET	The Institution of Engineering and Technology
KW	Kilowatt (one thousand watts)
KWh	Kilowatt hour
LCICG	Low Carbon Innovation Coordination Group
LCNF	Low Carbon Networks Fund
LOLE	Loss of Load Expectation
MSR	Molten Salt Reactor
MW	Megawatt (one million watts)
MWh	Megawatt hour
NBS	New Balancing Services
NETSO	National Electricity Transmission System Operator
NG	National Grid
NIRAB	Nuclear Innovation and Research Advisory Board
OFGEM	Office of Gas and Electricity Markets
PJM	Pennsylvania, New Jersey and Massachusetts
PV	Photovoltaic

R&D	Research and Development
RAEng	Royal Academy of Engineering
RD&D	Research, Development and Demonstration
RESNET	Resilient Electricity Networks for Great Britain Project
RIIO	Revenue = Incentives + Innovation + Outputs
SBR	Supplemental Balancing Reserve
SMR	Small Modular Reactor
ToU	Time-of-use tariffs
TW	Terawatt (one trillion watts)
TWh	Terawatt hour
TINA	Technology Innovation Needs Assessment
UKERC	UK Energy Research Centre
VoLL	Value of Lost Load