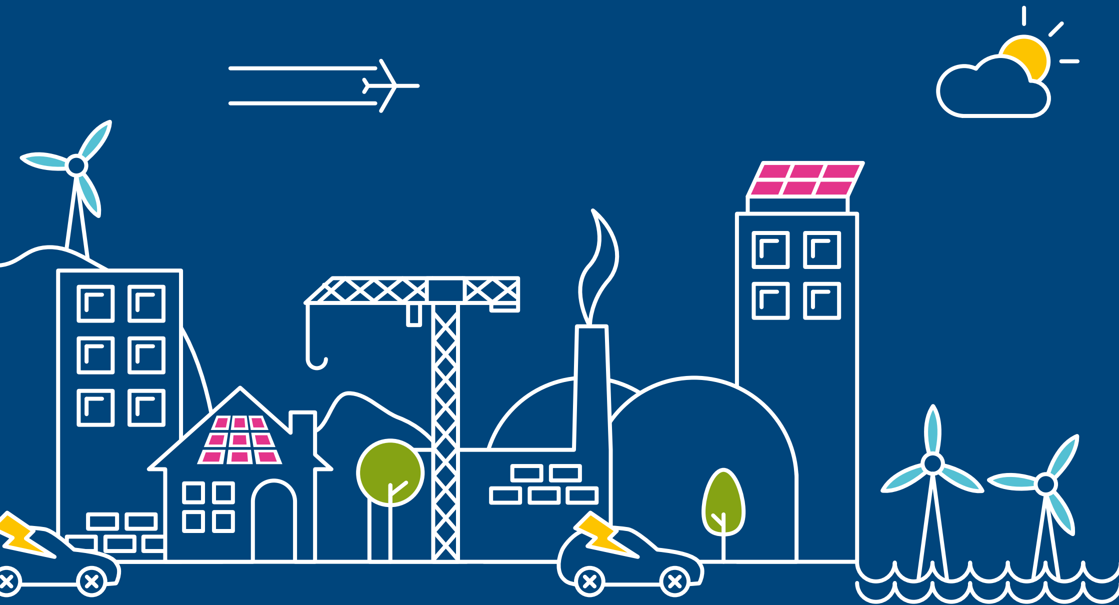
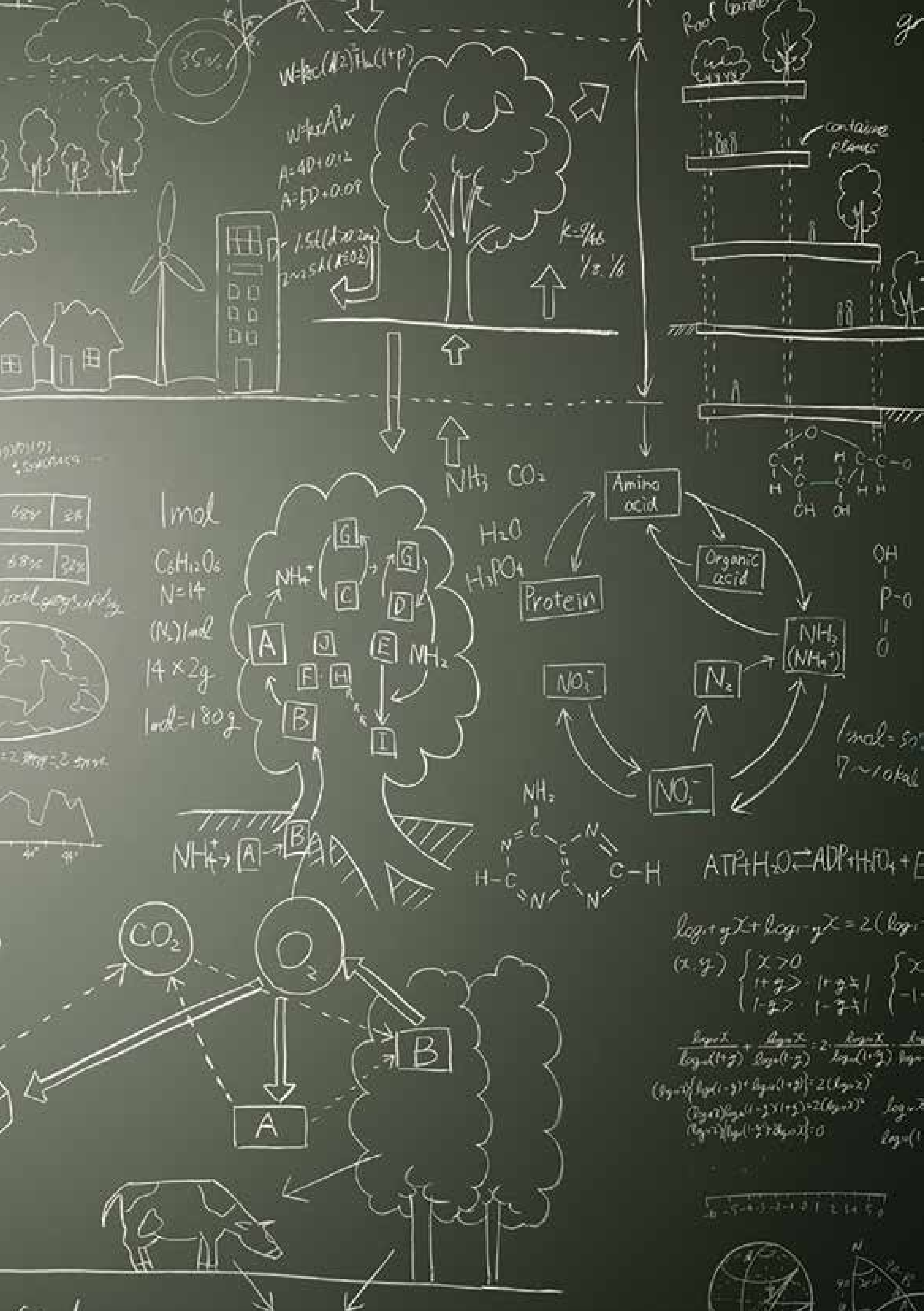
nationalgrid

Future Energy Scenarios

UK gas and electricity transmission



JULY 2015



Amino acid
Organic acid
Protein
1mol
N=14
14×2g
1mol=180g
NH3 CO2
H2O
H3PO4
CO2
O2
A
B

Ensuring that Great Britain has secure, sustainable and affordable sources of energy to fuel the future is one of the biggest challenges facing our nation.

Through our 2015 Future Energy Scenarios (FES) we explore how this complex energy landscape is changing and analyse how the future might play out.

We are only able to produce a set of credible future energy scenarios through the involvement of stakeholders from right across the energy sector. By participating in bilateral sessions and workshops or responding to questionnaires and providing comments you have really helped to shape our thinking.

We've also listened and acted on your feedback from FES 2014. This year we have introduced five high-level assumptions to simplify the presentation of our analysis. There is also a new scenario called **Consumer Power**, replacing the **Low Carbon Life** scenario, which you told us lacked the necessary clarity.

So, now that the detailed analysis is complete and we can take a step back to look at the overall picture for the energy environment, what does it tell us?

Two things strike me. The first is that uncertainty is here to stay. An uncertain economic, technological and consumer landscape provided the backdrop to our 2014 scenarios and we can expect more of the same in the coming years. The growth in small scale generation in GB offers one practical example, because we now have more locally generated and distributed electricity than ever before. As a large proportion of this never enters our transmission network, this means we see changing demand patterns on our network.

The second point is the increasingly global nature of the energy market. Great Britain is an island, yet it is true to say that our energy future will be driven not only by decisions taken at home, but by factors in Europe and elsewhere in a world that is becoming ever more interconnected. Over the last 12 months we have seen this play out in the GB gas sector with an increasing diversity of supplies, as well as fluidity in the liquefied natural gas (LNG) market. Similarly the electricity sector has seen an increase in planned interconnectors, responding to more price certainty from Ofgem's cap and floor announcements.

Without question there are some significant challenges ahead, including plenty to be positive about. By sharing insight, collaborating and taking action together, we can help the UK to meet its 2020 and 2050 energy targets, whilst at the same time ensuring security of supply for both electricity and gas. It is really important to me that consumers are at the heart of this debate to ensure they continue to enjoy secure, sustainable and cost effective energy.

I hope that you find this document useful as a catalyst for the wider energy debate that remains high on the agenda for all of us. We're keen to hear your views and you can get involved via our new website fes.nationalgrid.com, via our dedicated LinkedIn group page, Future of Energy by National Grid, and on Twitter via @nationalgriduk and #fes2015.

Roisin Quinn,
Head of Energy Strategy and Policy

Chapter one

Executive Summary

Executive Summary

Great Britain's energy landscape continues to change at an unprecedented rate. Diversity of supply has increased and globalisation has accelerated, from the international shipping of new sources of gas supplies to the cross border transfer of electricity in Europe. Managing these and other changes to the energy mix results in opportunities both for energy consumers and for future grid operation. This includes scope for significant innovation as we explore new tools to balance the network through changes in supply and demand and seasonal operability challenges.

Security of supply is achieved in all scenarios. The sources of power and gas supply flex across the scenarios as political, economic, technological and societal assumptions affect market conditions. Gas supply scenarios include a wide range of possible supply patterns. Import dependency increases in three of our four scenarios and the gas market is expected to provide enough gas from international markets to make up the difference between indigenous supply and demand.

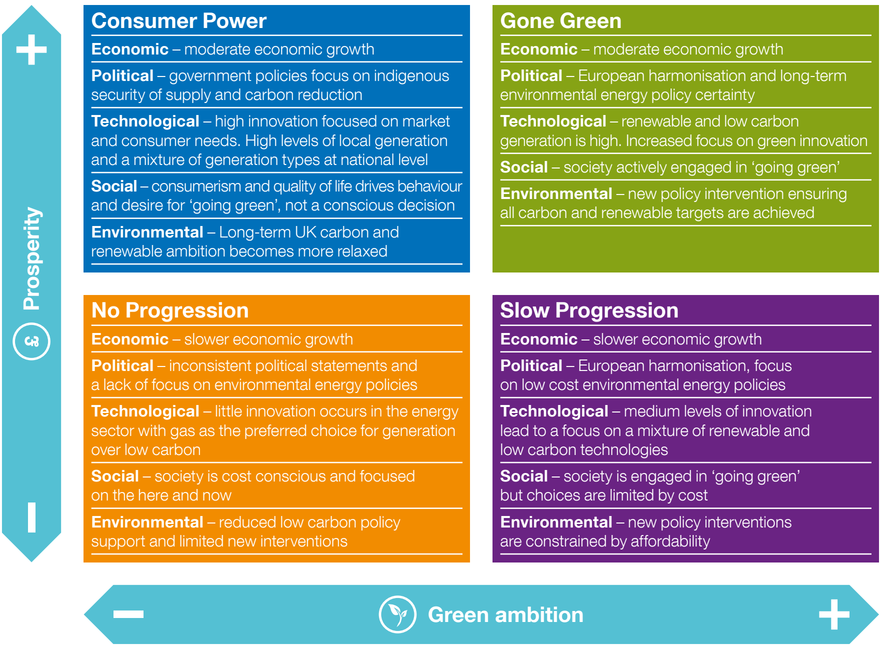
Power demand decreases in the short term across all four scenarios, before increasing to beyond today's level at different points in the future. In terms of gas demand two scenarios show an increase with two showing a decrease. Whilst the overall demands are similar between some of the scenarios there are different factors driving individual sectors.

1.1
An evolutionary approach to our Future Energy Scenarios for 2015

We have listened to your feedback and created a credible set of scenarios that has been approved by our regulator, Ofgem. This is in accordance with the recent modification of National Grid's Electricity Transmission Licence (ETL), requiring submission of our proposed scenarios to Ofgem each year.

Stakeholders were positive about our 2014 scenarios and suggested evolutionary, rather than revolutionary, improvements. In response to the feedback, we kept our scenarios based on the energy trilemma. We reworked the **Low Carbon Life** scenario into **Consumer Power** and replaced our "axioms" with a clearer set of five high level primary assumptions, which underpin the ranges of our modelling inputs.

Figure 1
Here are the political, economic, social, technological and environmental factors accounted for in our four 2015 Future Energy Scenarios



Executive Summary

- **Gone Green** is a world where green ambition is not restrained by financial limitations. New technologies are introduced and embraced by society, enabling all carbon and renewable targets to be met on time.
- **Slow Progression** is a world where slower economic growth restricts market conditions. Money that is available is spent focusing on low cost long-term solutions to achieve decarbonisation, albeit it later than the target dates.
- **No Progression** is a world focused on achieving security of supply at the lowest possible cost. With low economic growth, traditional sources of gas and electricity dominate and there is limited innovation changing how we use energy.
- **Consumer Power** is a world of relative wealth, fast paced research and development and spending. Innovation is focused on meeting the needs of consumers, who focus on improving their quality of life.

1.2 We have identified important themes emerging from our analysis on the future of energy

GB remains a net importer of electricity in three out of our four scenarios

- The investment climate for interconnectors has improved; there is increased investment certainty, aspirational interconnector targets and a strengthening need case due to high levels of intermittent generation.
- **Gone Green** is the only scenario showing exports by mid 2030s. This highlights the benefit interconnectors provide for nuclear and renewable generation, with low carbon generation able to reach a wider customer base across Europe.
- To account for this change we have increased interconnector capacities for FES 2015, with the highest being **Gone Green** at 17.7 GW by 2030. The lowest level of interconnection being in **No Progression** at 9.8 GW by 2030.

The scenarios highlight the increasing operability challenges the electricity industry faces

- Future summers will see periods of low transmission demands due to the increasing amounts of small scale generation.
- **Consumer Power** is our scenario with the highest levels of small scale solar generation. By 2020, demand seen on the transmission system will be as low as 16.7 GW on some days. With the output from low carbon generation at such a level, we will face system balancing challenges. Minimum demand could fall below 5 GW by 2030, which is below the expected level of inflexible generation.
- Innovative solutions will be required to address these challenges. For example, greater flexibility from existing sources of generation and demand, greater use of interconnection, the development of energy storage, more demand side response, and new balancing products.

Sufficient gas supplies are available in all scenarios with significant uncertainty on the source

- In all scenarios there is sufficient gas supply to meet demand, both on an annual and peak basis.
- The major variation between scenarios is the source of supply, be it indigenous or imported gas.
- **Consumer Power** sees our highest case for GB production from shale gas, with 32 bcm per year by 2030. This significant growth in shale gas from the mid-2020s reduces the need for gas imports.
- In contrast **Slow Progression** sees our lowest level of GB production. This results in an increasing requirement for gas imports with a 90% dependency by 2035. This could be provided either from continental Europe, or buying liquefied natural gas (LNG). The precise mix of these sources will be determined by the prevailing market conditions at the time.

Gone Green is the only scenario to achieve all renewable and carbon targets on time

- Renewable technologies contribute 34% of electricity supplied by 2020. Wind power contributes the vast majority of output, to achieve the 2020 renewables target, at 18% of total output.
- Beyond 2020 low carbon electricity, from a mix of renewables and nuclear, underpins the electrification of heat and transport. Heat pumps and electric vehicles provide an increasing contribution towards meeting the targets over time.
- In order to meet the challenges of long-term decarbonisation targets the heat sector requires a move away from gas towards electric heating.
- Whilst heat pumps become the largest provider of heat in 2050, there is still an essential role for gas to provide top-up heat.
- In the three other scenarios environmental targets are not met on time due to lower prosperity and less green ambition.

Margins, whilst narrow, continue to be manageable until 2018/19 when the capacity market delivers new sources of capacity and margin pressures ease.

- Our analysis shows the importance of putting in place products to access additional capacity to support management of winters with tight margins until the Capacity Mechanism is implemented. We are contracting with demand side balancing reserve (DSBR) and supplemental balancing reserve (SBR) providers to address this for winter 2015/16. This is shown in our security of supply case study in Chapter 7.
- In the longer term, security of supply improves with the contribution to capacity as a result of the Capacity Market; this is shown in all four scenarios from 2018/19.

90%
dependency on gas imports by 2035

Executive Summary

1.3 Key statistics

Consumer Power	2014	2020	2030
Power			
Annual demand, TWh	339	334	342
Peak demand, GW	60.4	60.7	62.6
Total installed capacity, GW	87	104	125
Low carbon capacity, GW	31	56	76
Interconnector capacity, GW	3.8	6.0	10.8
Gas			
Residential gas demand, TWh	321	302	292
Annual gas demand, TWh	818	859	851
Gas imports, %	58	55	34
Shale gas production, bcm	0	1	32
Decarbonisation			
Renewable energy, %	~7	~12	~19
Reduction of GHG emissions, %	30	52	57

No Progression	2014	2020	2030
Power			
Annual demand, TWh	339	335	333
Peak demand, GW	60.4	60.5	60.8
Total installed capacity, GW	87	93	101
Low carbon capacity, GW	31	43	48
Interconnector capacity, GW	3.8	6.0	9.8
Gas			
Residential gas demand, TWh	321	308	300
Annual gas demand, TWh	815	819	839
Gas imports, %	58	61	64
Shale gas production, bcm	0	1	16
Decarbonisation			
Renewable energy, %	~7	~10	~11
Reduction of GHG emissions, %	30	49	52

Gone Green	2014	2020	2030
Power			
Annual demand, TWh	339	329	362
Peak demand, GW	60.4	59.3	66.1
Total installed capacity, GW	87	96	136
Low carbon capacity, GW	31	53	98
Interconnector capacity, GW	3.8	10.8	17.7
Gas			
Residential gas demand, TWh	321	284	200
Annual gas demand, TWh	811	710	602
Gas imports, %	58	52	68
Shale gas production, bcm	0	0	0
Decarbonisation			
Renewable energy, %	~7	~15	~30
Reduction of GHG emissions, %	30	54	64

Slow Progression	2014	2020	2030
Power			
Annual demand, TWh	339	335	332
Peak demand, GW	60.4	60.3	59.4
Total installed capacity, GW	87	96	117
Low carbon capacity, GW	31	48	74
Interconnector capacity, GW	3.8	8.4	14.2
Gas			
Residential gas demand, TWh	321	294	274
Annual gas demand, TWh	814	756	702
Gas imports, %	58	66	88
Shale gas production, bcm	0	0	0
Decarbonisation			
Renewable energy, %	~7	~13	~22
Reduction of GHG emissions, %	30	51	60

Executive Summary

1.4
The role of stakeholders

Stakeholders are fundamental in the development of our Future Energy Scenarios, driving the range, content and advancement of our analysis. As important users of the outputs of the FES process, our stakeholders create and deliver the component parts needed to deliver the energy systems of the future.

We value the opinions and contributions from across the sector and the wider community to ensure we have a complete and rounded understanding of current and future market activity. We actively seek out industry experts to bring knowledge and new thinking to our analysis. Equally important is the wider debate and discussions we use to challenge and review our market assessment.

Many stakeholders are impacted by our business and influence our decisions at every stage of our operation; from identifying the energy mix of the future, through to building new pipes, overhead lines and cables and operating this new infrastructure. It is therefore essential that our stakeholders have the opportunity to understand and debate the scenarios in detail to evolve and improve the outputs each year.

The publication of this document each summer represents the beginning of a new cycle of engagement. Over the last few years we have significantly increased the involvement of our stakeholders in the development of our scenarios. We interact with a diverse range of stakeholders with a wide set of interests.

In the last 12 months we have engaged with over 350 people from 233 organisations including industry, the government, regulators, professional and special interest groups, customers and consumers. Last autumn we hosted three large-scale conferences to discuss the scenarios and gather feedback from the previous year's report. We engage our stakeholders using a mixture of one-to-one meetings, topic-specific discussions with small groups of experts from one or more companies, and sector-specific workshops involving a larger number of organisations. Working closely with interest groups and trade associations, we proactively seek a diverse range of views to maximise the depth and diversity of the inputs to our scenarios and analysis.

1.5 Responding to your feedback

This year's stakeholder views were positive about FES 2014 in terms of scope, content, process and delivery. We were told that no radical changes were required, so we have adopted an evolutionary approach to FES 2015.

The most noticeable change has been to our **Low Carbon Life** scenario. Stakeholders told us it was difficult to understand as there were underlying inconsistencies in the rationale which made the results unclear. For 2015 we have re-worked this scenario, renaming it **Consumer Power**.

The energy trilemma is used as the foundation for our scenarios. Many stakeholders found this very useful to provide a common narrative across the energy industry so it continues to be the basis of our analysis in 2015.

Stakeholders told us the axioms we used in our analysis and modelling can help them to better understand the scenarios. However it was clear from the 2014 feedback that there were too many axioms and having no hierarchy was confusing. Based on this feedback, we have replaced the axioms with five high-level primary assumptions which drive the ranges of all the modelling inputs to the four scenarios.

We presented our scenarios in a 2x2 matrix, and this approach received strong positive feedback. In 2014, sustainability and affordability were used as the axes descriptions for the matrices and some stakeholders felt these were unclear. For 2015, the axes have been revised to prosperity and green ambition.

Our FES Stakeholder Feedback Document summarises our stakeholder engagement each year. This publication gives more information to understand how we have engaged, what our stakeholders have been telling us, and how we intend to act on the feedback.

Executive Summary

1.6 What FES is…

A range of credible futures.

An output of an annual stakeholder consultation process regarding the future of the energy landscape.

A document covering the model inputs to the scenario analysis, new technologies, social and economic developments, government policies and progress against targets.

A set of scenarios which can be used to frame discussions and perform stress tests.

A set of scenarios that are projected out from the present to 2050.

Scenarios which form the starting point for all transmission network and investment planning. They are also used in analysis to identify future operability challenges and potential solutions to meet those challenges.

A document covering developments in electricity generation and demand, and gas supply and demand.

What FES isn't…

The document does not cover potential network developments: these are addressed in the gas and electricity ten year statements.

Costs are not applied to the scenarios. There is too much uncertainty for any numbers to be credible.

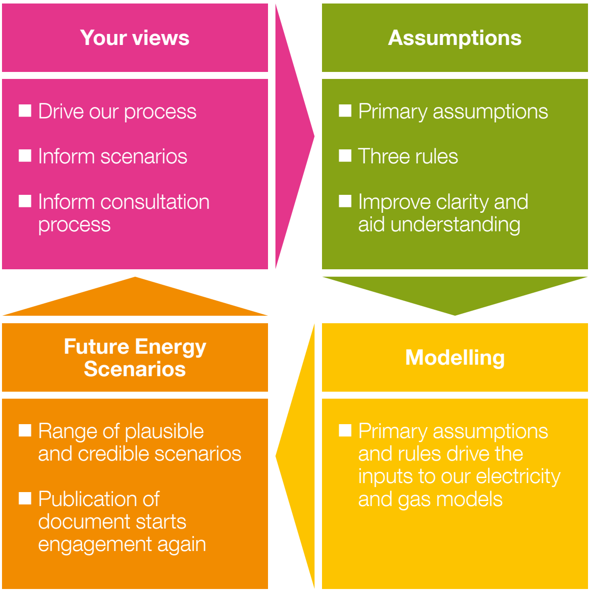
The document does not provide a forecast of the future. Scenario planning does not predict the future; rather it considers a scope of potential drivers that may have an impact.

There is no probability analysis undertaken and not one of our scenarios is deemed more likely than another.

Executive Summary

1.7 Improving stakeholder involvement

We are never complacent and recognise that there are always ways that our stakeholder engagement could be improved. For 2015, we are planning to make our engagement broader, deeper and smarter with improvements to the value added to the outputs.



By targeting, co-ordinating and listening more actively, we believe our engagement will be significantly smarter. A 'one-size-fits-all' approach is not appropriate for our diverse range of stakeholders. We will explore a wider range of engagement methods. The new dedicated FES website is just one of a number of developments we are making to provide a more open and transparent source of engagement opportunities.

Deeper engagement will concentrate on understanding how our scenarios are used by stakeholders. We will explore opportunities for more collaborative engagement to aid the development of primary assumptions and modelling inputs to give richer, better outputs.

Broader engagement with new stakeholders is important to develop more robust scenarios. For example, we work with a range of UK and European organisations to identify best practice in scenario development and stakeholder engagement. We will build on these relationships, adding new organisations where appropriate.

1.8 Scenario development

Feedback is fundamental to the development of our FES. With an improved understanding of all our stakeholders' views on the future of energy, we can develop a rich suite of energy scenarios that will enable us to address the long-term strategic challenges facing the development of the gas and electricity transmission networks in GB.

Our stakeholders' views are at the heart of the scenario creation process, from developing the primary assumptions and model inputs, through to the scope and content of our FES.

Executive Summary

1.9
How to use this document

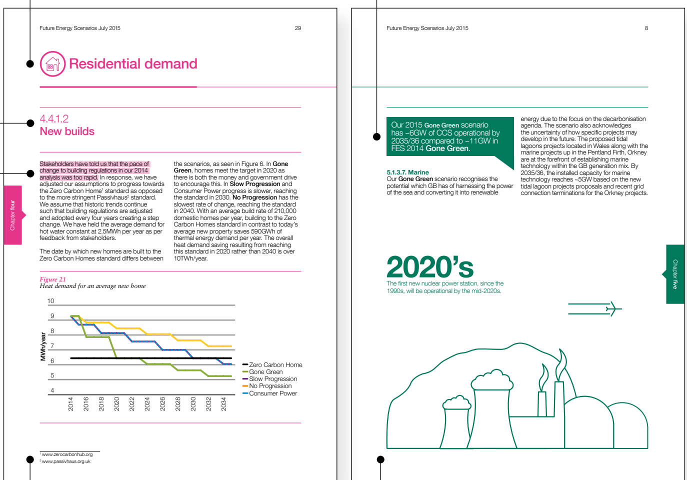
This document has been designed to present information in easily digestible sections, with the subject matter clearly defined in colour-coded chapters.

Heading and icon introduce the main topic on the page.

Key pieces of information are highlighted in boxes.

The main text is divided into sections by subheadings.

We have highlighted specific areas where we have responded to stakeholder feedback.



Footnotes are used for citations and further commentary.

Key data is emphasised with an image.

Chapters are tabbed and colour coded to help you find the section you are looking for.

Chapter two

Scenarios

Scenarios

Gone Green is a world where green ambition is not restrained by financial limitations. New technologies are introduced and embraced by society, enabling all carbon and renewable targets to be met on time.

In a **Gone Green** world there are high levels of prosperity; consumers are able to buy new appliances and technologies, industrial and commercial users have investment capital available and the government has more money available for incentives. There is a high level of green ambition across all sectors of the economy, with new policies introduced to reduce emissions. This green ambition extends across Europe, with harmonisation and long-term environmental energy policy certainty.

Power generation is focused on decarbonisation due to policy drivers introduced by the government. With moderate economic growth, generation build rates are at their highest in this scenario. There are high levels of renewable generation and new technologies such as marine and Carbon Capture and Storage (CCS) generation.

Decarbonisation of the power supply is required to meet the 2020 and 2050 targets, especially in response to the increasing demand for power in this scenario. Power demand is higher as electricity is used to meet a significant proportion of heat and transport demand. To manage the impact of increased demands at peak times, there is a significant uptake of time of use tariffs (TOUTs) and the smart metering deployment is delivered on time by 2020.

In response to popular green sentiment regulations are introduced which make shale gas development uneconomic. Money is instead invested in innovative green technologies, which are supported by government policy; biomethane production is high.

3.2GW

Amount of additional onshore wind, installed by 2018

10GW

Amount of additional wind generation, installed by 2020

27M

Amount of smart meters installed by 2020

900,000+

Number of heat pumps installed by 2020

500,000

Number of electric vehicles by 2020

10%

The level of interconnection reaches the EU capacity target of 10% by 2020

Residential users
With one in six cars being an electric vehicle (EV) by 2035, you or someone in your close family will be driving an electric vehicle in this world. You may choose to substitute some car trips by taking a natural gas powered bus.

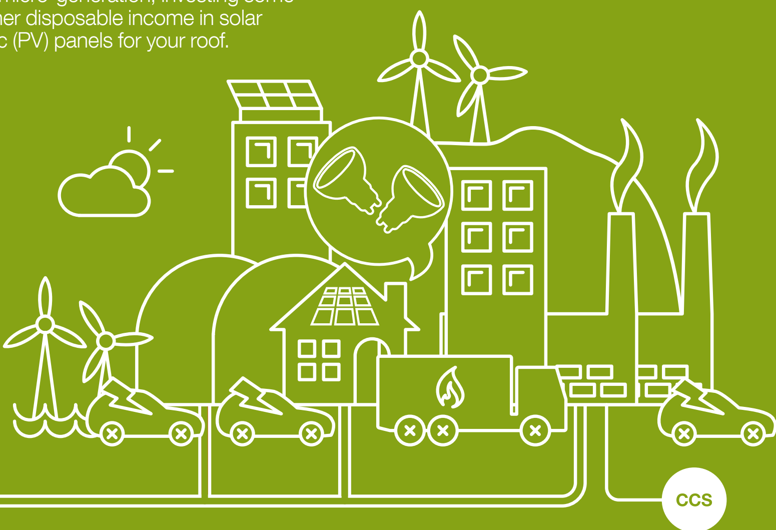
When buying a new home you will see more energy efficient homes on the market; and if you buy a new one after 2020 you will purchase a Zero Carbon Home. If you are not moving home you will invest in as much insulation as your house needs to improve its energy efficiency rating. You will have greater control over your energy use, and a greater desire to reduce your demand, facilitated by smart meters and home energy management systems like smart thermostats. Your TOUTs will enable you to save money and energy by shifting your energy use away from peak times, such as turning on appliances overnight. You will have abandoned the use of halogen lighting in favour of the more efficient light emitting diode bulbs (LEDs).

Low carbon heating technologies are appealing due to their green credentials and so you invest in a heat pump in your home. The new estate nearby is heated by a district heat network where the heat is generated centrally, most likely by a biomass combined heat and power (CHP) unit. It's likely you or a neighbour choose to invest in micro-generation, investing some of your higher disposable income in solar photovoltaic (PV) panels for your roof.

Industrial and commercial users
Your HGV fleet progresses towards natural gas and later towards hydrogen fuelled vehicles, as this is the most economic and environmentally friendly option for your business. You replace your existing light bulbs with highly-efficient LED bulbs to reduce your emissions and electricity bills. You consider installing a biomass fuelled CHP unit to generate your own clean electricity.

2030
The investment climate and pilot project outcomes support the commercial rollout of carbon capture and storage (CCS) by 2030

2050
Date when almost all power generation is decarbonised



Scenarios

Slow Progression is a world where slower economic growth restricts market conditions. Money that is available is spent focusing on low cost long-term solutions to achieve decarbonisation, albeit it later than the target dates.

Slow Progression is a world where residential, industrial and commercial users and the government are all striving towards a **Gone Green** world, but the lower economic growth slows progress. There is harmonisation at a European level, with a focus on low cost environmental energy policies. The limited innovation money available is spent on renewable and low carbon technologies, as there is limited government money to support development.

Policies support renewable and low carbon generation, however build rates are hampered by the lower economic growth in this world. Expensive technologies such as marine receive less investment, whilst wind and solar generation reach medium levels. Thermal generation is still a major part of power generation, with gas and nuclear favoured over coal.

UK continental shelf (UKCS) development is limited due to taxes, and new regulation makes shale gas uneconomic. The limited investment is focused instead on innovative green technology. Regulation does support biomethane production and some innovation money is invested in new production techniques.

Consumers, in an effort to reduce energy use in order to save money and reduce emissions, invest where they can in efficient products. Smart appliances are a focus area of spending and many people take up TOUTs. Micro-generation is introduced where possible, but the high gas price focuses installations away from gas CHP units. Building regulations are tightened to reach the Zero Carbon Homes target by 2020 and cost-effective insulation rates are high.

8.4GW

The level which electricity interconnection increases to by 2020

9GW

Amount of wind generation installed by 2020 – a year behind Gone Green

1.9%

Average annual economic growth

Residential users

You want to reduce your impact on the environment and reduce your energy bill but have less money to purchase expensive technologies. You are willing to invest in solar PV when possible. You seek out cost effective ways to manage your energy use and consider TOUTs and home energy management systems where you can afford them.

Any new appliances that you buy are more efficient, as this has become the only option following policy and regulation. You do all you can to ensure your home is energy efficient, insulating your loft and cavity walls.

You would like to buy an electric car but may not be able to afford it; hybrid vehicles offer a cheaper solution. The decarbonisation of public transportation is a government priority and receives support, and you often choose to take the bus instead of drive.

Your heating system is likely to remain gas or electric until 2030; there has been less innovation in low carbon heating technologies which leaves heat pumps and micro-CHP too expensive.

Industrial and commercial users
Environmental policies and the green focus of consumers drive you towards improving your energy efficiency and investing in green technologies where possible. The slower economic growth restricts you from investing in expensive technologies with long pay-back periods so you opt for smaller projects such as insulating buildings and purchasing LED light bulbs.

You are slowly transitioning your HGV fleet to natural gas vehicles, it is more economical but the required upfront capital to purchase new vehicles or convert your current stock remains a barrier. You may also consider saving to invest in a biomass CHP plant to reduce your energy usage if the payback period is economical.

300,000+
Vehicles are electric by 2020

3,000
Approximate number of micro-CHP units in homes/properties in 2020

Scenarios

No Progression is a world focused on achieving security of supply at the lowest possible cost. With low economic growth, traditional sources of gas and electricity dominate, with little innovation affecting how we use energy.

No Progression is a world of low economic growth and inconsistent political signals with a lack of focus on environmental policies. Society is cost conscious and focused on the here and now.

Power generation is focused on achieving security of supply at the lowest possible cost. As such, there is minimal innovation and traditional generation remains high; with gas prevailing over low carbon and renewable technologies.

Today's level of support for UKCS and biomethane continues into the future but is not sufficient to drive significant growth with medium market prices. The limited innovation is focused on technology with high production rates, hindering biomethane production and holding shale gas and UKCS developments at a medium to low level.

Consumers choose to spend their money to receive immediate and direct benefits, and are not driven to reduce their energy usage. The lack of innovation in the energy industry also affects consumer choice when making purchases. This leads to a low uptake of micro-generation, electric vehicles and smart appliances.

The makeup of the heat and transport sectors does not differ significantly from today. Heat is dominated by traditional gas appliances as there is limited growth in both low carbon technologies and heat networks. Petrol and diesel vehicles dominate in the public, private and business use sectors as the cheapest option.

1M

Consumers are engaged TOUT users in 2020

<200,000

Vehicles are electric in 2020

1.9%

There is an average annual economic growth of 1.9%

Residential users

In a **No Progression** world your primary driver is cost. You don't have the money or the inclination to spend time and money on green technologies. Due to a lack of policy support, you do not see many renewable or energy efficient products on sale and choose to continue with the products that you know and trust.

For most products that you own, you would rather keep them than replace them. You don't replace your car or appliances unless they break and you are not engaged with smart meters or TOUTs. If you are looking for a new home you do not seek out improved energy efficiency ratings or low carbon heating technologies.

Industrial and commercial users
The slow economic growth and inconsistent government policy do not drive you to make many significant changes from today's rate of progress. The lack of political support and incentive schemes cause you to maintain your current activities rather than invest in new technologies. You have no inclination to switch to low carbon or renewable sources of energy, and the lack of innovation in these sectors causes prices to remain high and uneconomical for many.

You have not changed your vehicle fleet, choosing not to invest in gas or electric vehicles.

Electricity prices are low and, without environmental taxation, there are fewer incentives to reduce your energy usage. As such you see no reason to replace your light bulbs with LEDs. Nor would you feel inclined to take advantage of demand side response activities, even if it is available.

2040

Residential houses don't reach the Zero Carbon Homes target for energy efficiency until 2040

6M

Smart meters installed by 2020

35%

Gas is the dominant fuel source for generation, making up around 35% of installed capacity in 2020

Scenarios

Consumer Power is a world of relative wealth, fast paced research and development and spending. Innovation is focused on meeting the needs of consumers, who focus on improving their quality of life.

Consumerism and quality of life drive decisions in this scenario. There is a more relaxed ambition to renewable targets, with government policy focusing instead on indigenous security of supply and low carbon technologies. The moderate level of economic growth ensures that there is money available for the government, consumers and industrial and commercial users to spend and invest. As a result innovation is high and research and development continues at a fast pace.

The primary fuel for both large and small scale generation is gas, due to the relatively low gas prices. This economic driver results in localised generation becoming prominent, including micro-CHP units. While there is a push towards low carbon generation this materialises in high levels of solar and gas CHP.

In response to the high demands for gas for power generation, increased gas supplies are required. Despite the low gas prices, regulatory support makes investment in gas sources economical. With this support, and a focus on innovation and investment capital, shale production levels are highest in this scenario. Additionally, low taxation helps to drive further development in UKCS.

Energy demand is driven by consumer preferences, and the market responds by focusing on innovating to attract customers to new products. Although some technologies do reduce energy usage, such as home energy management systems, smart appliances and electric vehicles, this is a by-product rather than the main selling point. This is the only scenario to see a high level of demand for air-conditioning as consumers value higher quality of living over reducing emissions. Manufacturers invest in continued development into electric vehicles and they are desired by consumers as a luxury item, regardless of the lower green ambition. Public transport does not see the same level of investment in electric or gas vehicles, due to the low environmental concerns. There is only a medium amount of decarbonisation achieved in order to improve air quality for consumers.

Heat demand, in the residential, industrial and commercial sectors is dominated by gas. This is comprised of traditional gas boilers, micro-CHP units and larger CHP plants.

120,000
Micro-CHP units installed in homes in 2020

18GW
Solar PV installed by 2020

100
Shale sites developed by 2030

Residential users
As a consumer in this world you spend your money on your family and yourself, enjoying the relatively prosperous economic growth. You choose to invest in some smart appliances and a new electric vehicle, because they are new and luxurious and make everyday life easier for you.

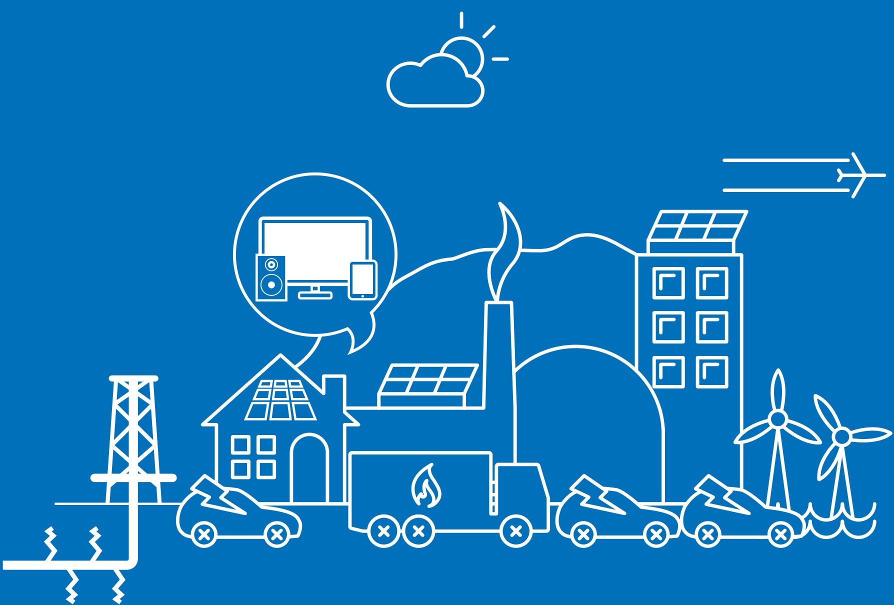
If you have money available to invest, the low gas prices make installing a micro-CHP unit in your home an economical decision, replacing your gas boiler. You consider solar PV as a source of income, taking advantage of affordable panel prices.

Industrial and commercial users
As in **Gone Green**, your HGV fleet is comprised of natural gas vehicles as they are by far the most economical. You install a CHP unit to take advantage of the discrepancy between gas and electricity prices and reduce your electricity demand and switch from power to gas for heating and hot water needs. You also consider purchasing LED lighting when your old bulbs need replacing.

2.4%
Average annual economic growth

33.3%
Small scale generation accounts for a third of power generation capacity by 2020

3%
Of HGV fleet are gas vehicles by 2020



Chapter three

Landscape

Landscape

3.1 Three rules

For our 2014 Future Energy Scenarios we had 26 axioms that described the fundamental assumptions that underpinned our scenarios. Some of our stakeholders felt that 26 was too many and there was a lack of structure to them. For 2015 we have listened to our stakeholders and replaced the axioms with three rules and five primary assumptions. These drive all of the ranges for inputs to our various models. We believe this increased clarity will aid understanding.

Figure 2
The three rules

Levy control framework	Security of supply (Electricity)	Security of supply (Gas)
Spending capped at £7.6 billion in line with the LCF trajectory out to 2020/21	Abide by security standard as prescribed by secretary of state (currently three hours/year loss of load expectation)	There will be sufficient capacity to ensure that the N-1 test will continue to be satisfied

3.1.1
Levy control framework (LCF)

The LCF allows Government to control the overall costs of its levy-funded policies associated with the support of renewable generation. The LCF sets annual limits on the levels of support to limit the impact on consumers' energy bills with an overall cap of £7.6bn in 2020/21. This rule has been applied by limiting the deployment of renewable generation to ensure the cap isn't breached in any scenario. This has the most impact in **Gone Green** as the scenario with the largest deployment of renewable generation.

3.1.2
Security of supply (electricity)

The government has set a reliability standard for the GB market at a level which balances the impact of failure to deliver sufficient energy with the cost of capacity required to provide that energy. This standard is based on loss of load expectation (LOLE). LOLE measures the risk across the whole winter of demand exceeding supply under normal operation. It does not mean there will be loss of supply for X hours/year. It gives an indication of the amount of time across the whole winter the System Operator (SO) will need to call on balancing tools such as voltage reduction, maximum generation or emergency assistance from interconnectors.

In most cases, loss of load would be managed without significant impact on end consumers. The standard for GB is set by the government at 3 hours/year LOLE. This rule has been applied when developing the FES generation backgrounds.

It ensures that, post introduction of the Capacity Market in 2018/19, there will be sufficient capacity on the system to meet this standard.

[1] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:295:0001:0022:EN:PDF

[2] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/318466/gas_risk_assessment.pdf

Landscape

3.1.3
Security of supply (gas)

There will be sufficient capacity to ensure that the N-1 test will continue to be satisfied. This rule has been added for 2015 to provide a clear definition of the security of supply standards applied to gas. The N-1 test assesses whether peak demand could still be met if you lost the largest single piece of infrastructure. This rule is used by the European Commission[1] and in the UK the assessment is published by Department of Energy and Climate Change (DECC) in the UK Risk Assessment on Security of Gas Supply[2].

This rule ensures a consistent method is applied for security of supply for gas across all of our scenarios. It also allows comparison with other countries.

If there is not sufficient existing supply capacity to pass the N-1 test then additional capacity will be added to the scenario. To ensure the required level of new capacity can be delivered it will be based on the current view of potential import and storage projects. This is both in terms of the overall level of capacity and the expected start dates. However no single project will be selected to provide this capacity, instead it will be a generic scheme based on a number of projects which could meet this need.

3.2 Primary assumptions

The primary assumptions, in addition to the three rules, drive the modelling in the scenarios and replace the previous set of axioms. Many of our stakeholders found 26 axioms too many with no hierarchy or structure. Adopting five high-level assumptions allows the FES reader to see, more easily, what underpins the scenarios.

Figure 3
The primary assumptions

Landscape

3.2.1
Economic growth

Our economic primary assumption acts vertically across our four scenarios. We use a range of half a percentage point between the higher and lower economic growth forecasts used in our scenarios. This is unchanged from our 2014 modelling assumptions.

Higher economic growth is assumed in **Gone Green** and **Consumer Power**. Here, there is an average gross domestic product (GDP) growth of around 2.4% pa. This figure is based on Experian's central GDP forecast. We assume the economic recovery continues on its current trajectory, leading to higher household disposable income (HHDI) and the option for consumers to invest. This growth cascades down to provide gross value added (GVA) for sectors; this is also used in our econometric demand modelling. Corporations enjoy higher growth influencing their energy technology investment decisions.

Lower economic growth is assumed in **Slow Progression** and **No Progression**. These figures have been calculated from flexing Experian's central forecast down, using Oxford Economics' model, to give an average GDP growth of around 1.9% pa. This lower case represents a slowing of economic development in Great Britain, perhaps influenced by eurozone pressures. HHDI rises here too, but at a slower rate, dampening enthusiasm for investment. The same slower growth rate is experienced by corporations too, leading to lower, more constrained investment for technologies with a longer payback period.

3.2.2
Energy user behaviour

Our primary assumption of energy user behaviour covers a range of factors that feed into our modelling. Broadly speaking, the assumption considers how people and corporations engage with energy. This includes how and when they use it and their ambition to go green. Assumptions covered in energy user behaviour are:

- time of use tariffs (TOUTs) and demand side response (DSR)
- energy efficiency of buildings
- ambient room temperatures
- buying efficient goods
- self-generation of electricity (eg. solar photovoltaic panels (PV))
- investment in technology upgrades and research and development
- electric vehicle (EV) deployment.

These assumptions will help to define the impacts of schemes such as TOUT. More consumer engagement with energy may translate to shifts away from peak demand periods, or the faster deployment rate and required economics for new technologies like electric cars. Premise efficiency refers to insulation of homes and buildings which, along with ambient room temperature, impacts the thermal energy demands of buildings.

With higher energy user behaviour, consumers are engaged in moving their energy demand away from peak periods. They are also buying green technologies like solar panels, energy efficient white goods and electric vehicles. Additionally, corporations are making higher levels of investment in energy efficiency.

On a personal level there is a conscious effort to use less energy and seek cleaner sources. Conversely, lower energy user behaviour is characterised by less importance assigned to energy reduction, as greater priority is given to other factors, such as cost and convenience.

3.2.3 Technology

Our technology primary assumption considers the development and distribution of relevant technologies. This governs our assumptions on the rate of technological innovation. This assumption also considers the impact on affordability, the speed of deployment (including the formation of supply chains that affect availability), replacement rates (the rate at which newer technologies replace older ones) and improvements in energy efficiency of technologies.

Deployment rates and replacement rates are included in both the energy user behaviour and technology assumptions. The energy user behaviour assumption is concerned with the demand side, such as consumer buying behaviour. The technology assumption governs the supply side of the equation. Higher innovation also governs the behaviour of corporations looking for greener solutions or products. Note that the innovation referred to here is realised innovation, rather than ambition.

With higher technological developments more products come to market, which are more price competitive and energy efficient than existing technologies. For example, heat pumps become more competitively priced compared to gas boilers, as do LEDs compared to halogens. Products are also well marketed leading to faster deployment rates. So, if there is a reason to replace a product before the end of its life, perhaps to take advantage of increased functionality or reduced operating costs, then replacement rates will be accelerated.

This assumption also covers technology used in energy production. This includes techniques used to maximise gas production and both large and small scale power generation. For each scenario the comparative level of green ambition and prosperity will impact on whether the technological developments are focused on progressing greener solutions, or towards maximising security of supply.

Landscape

3.2.4 Policy

Our assumptions on policy cover a wide range of areas. These include targets for renewable energy, CO_2 emissions, energy efficiency and oil and gas production. The assumptions cover both policy aims and the support mechanisms to achieve them.

The greater level of green ambition in both **Gone Green** and **Slow Progression** sees new renewable energy targets introduced for 2030, 2040 and 2050. Alongside these there are targets for the level of interconnection. There are also increased energy efficiency standards for manufacturers and retailers of household goods, plus schemes to increase efficiency in the industrial and commercial sectors. Stricter controls are placed on both exploration and production of onshore oil and gas.

The less prosperous **Slow Progression** has a greater focus on delivering lower cost solutions, limiting the effectiveness of some policies. In the more prosperous **Gone Green** scenario greater levels of support are available to ensure policy aims are met.

With a lower level of green ambition in **Consumer Power** and **No Progression**, no new renewable energy targets are introduced and existing targets are relaxed. No new standards are introduced for energy efficiency. There are no changes to the existing regulations concerning onshore oil and gas extraction.

The more prosperous **Consumer Power** scenario sees existing levels of support for energy efficiency schemes maintained with greater incentives available to increase indigenous energy production. By contrast, in **Slow Progression** existing incentives for energy production are maintained but there is less support for energy efficiency schemes.

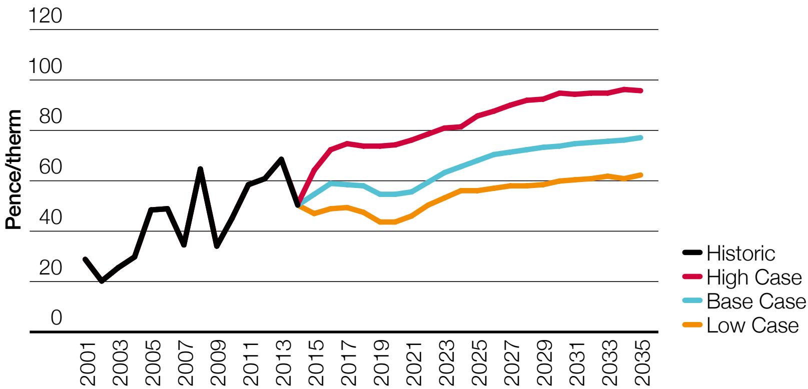
3.2.5 Wholesale fuel prices

Fuel prices can have a significant effect on energy demand. They form an important part of our analysis in determining the energy supplies and demands that feature in our scenarios. All prices have been adjusted for inflation to derive real prices applicable for 2015.

For instance, when modelling power supply, the different sources of available generation, the relative wholesale prices for gas, coal and UK carbon are important in determining what generation fuel will be favoured. The results will have a direct impact upon total gas demand which, in turn, will influence gas supply.

We develop our fuel price projections based on a number of different sources including government agencies, energy consultants, financial institutions and trading houses.

Figure 4
Wholesale gas prices (NBP)



National balancing point (NBP) Gas

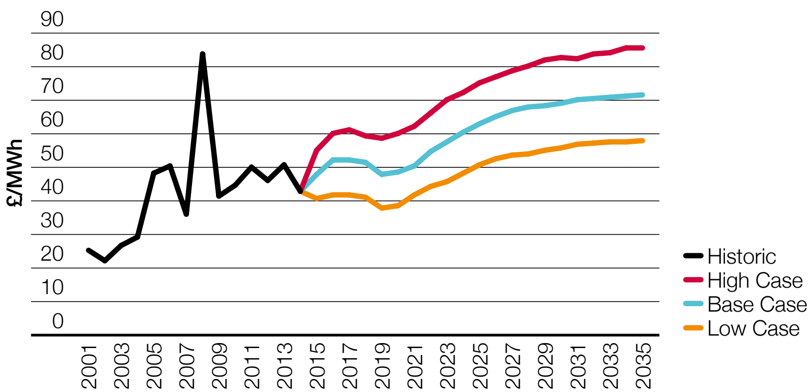
In the short term we expect gas prices to increase or remain flat. As the UK attempts to deliver on its climate and carbon reduction policies, gas usage in the power supply sector will increase. In the longer term, renewables and low carbon power sources increase their contribution in the power supply mix, reducing gas demands.

Towards the end of the decade NBP prices temporarily decline as new liquefied natural gas (LNG) supplies become available from North America (Figure 4). The differences in the gas supply ranges reflect the uncertainties in:

- increasing gas demands in China and India and the impact upon global LNG demands and costs
- the impact on Japanese LNG imports from the restart of nuclear power generation in Japan
- proposed liquefaction export projects from North America and Africa
- UK and European indigenous gas production – including shale gas production
- nuclear power generation in GB.

Landscape

Figure 5
GB base load electricity prices



Baseload electricity

We expect baseload electricity prices to increase or remain flat over the short term. System margins remain low as coal-fired plants close to adhere to the Industrial Emissions Directive (IED), and some gas-fired generation plants are closed or mothballed. Prices decrease towards the end of the decade as lower cost gas generation increasingly factors into the power price.

Figure 5 shows that power prices increase after 2020 as the cost of fuel increases and low carbon or renewable generation increasingly influences generation costs. The differences in the baseload power price ranges reflect the uncertainties in:

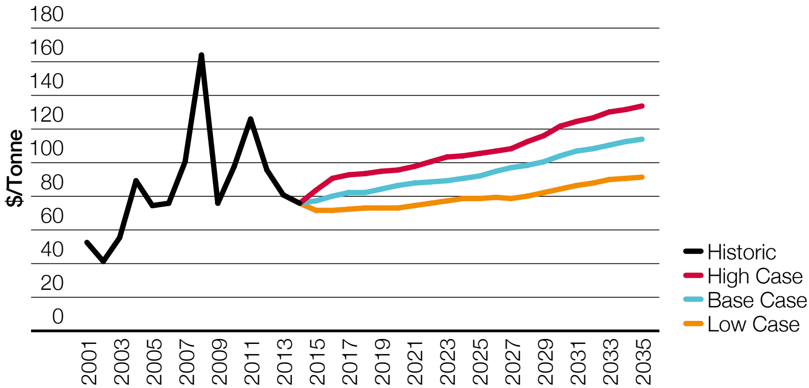
- the cost of generation required (low carbon or thermal) to maintain margins
- the timeliness of new nuclear generation in GB
- wholesale fuel prices for thermal power generation

Coal Prices Amsterdam, Rotterdam and Antwerp (ARA)

Coal prices are expected to steadily increase (Figure 6) as global coal demands remain high. The differences in the coal price ranges reflect the uncertainties in:

- the impact of the Chinese emission and energy policies on coal demands
- the impact of global oversupply if suppliers increase exports in order to maintain revenue
- the impact of climate policies on coal demands in the USA
- the impact of the IED on coal demands for the EU power generation sector
- coal demand increases from India and developing countries
- the impact on Japanese coal imports from the restart of nuclear power generation in Japan.

Figure 6
Wholesale coal prices



Carbon

As part of its commitment to the 1997 Kyoto protocol, the EU Emissions Trading Scheme (ETS) was established in 2005 to incentivise reductions in greenhouse gas emissions from large carbon-intensive industries and electricity generators. The scheme puts a cap on the amount of carbon dioxide (CO_2) that can be emitted and creates a market trading price for carbon allowances that are bought and surrendered in relation to the amount of CO_2 emitted. The costs are determined via a market mechanism which is impacted by the total amount of CO_2 produced and the number of carbon allowances granted by the EU.

A UK carbon price floor (CPF) was introduced on 1 April 2013 to guarantee a minimum price for CO_2 emissions. The CPF was set at £16 per tonne of CO_2 (tCO_2) for 2013 and was expected to rise by £2 per year to £30 tCO_2 by 2020.

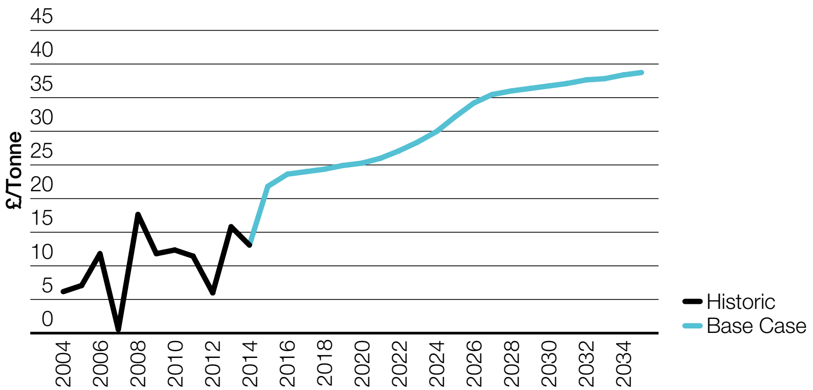
The floor price is achieved by adding a carbon price support (CPS) cost on top of the EU ETS.

To tackle low prices, because of an oversupply of ETS allowances in 2014, the EU started to withhold some 900 million carbon credits from the market. In addition, the UK Government announced a price freeze on the CPS rates in the 2014 budget, in order to ensure the UK remains a competitive location for manufacturing. As a result CPS rates will be capped at a maximum of £18 tCO_2 from 2016/17 until 2019/20, effectively freezing CPS rates at around 2015/16 levels.

The UK carbon price is expected to increase slightly until the end of the decade as the EU ETS prices increase. Longer term the CPS price increases are assumed to be limited or frozen.

Landscape

Figure 7
UK carbon prices



Prices and the FES 15 scenarios

We have used the prices to drive development of FES 2015 scenarios for gas and power demand and power supply.

Figure 8 summarises how the prices have been applied in each of the scenarios.

Figure 8
Fuel price summary

Consumer Power	Price scenario
Baseload electricity	Medium
Gas NBP	Low
Coal ARA	Low
Carbon	Medium

Gone Green	Price scenario
Baseload electricity	Medium
Gas NBP	Medium
Coal ARA	Low
Carbon	Medium

No Progression	Price scenario
Baseload electricity	Low
Gas NBP	Medium
Coal ARA	Low
Carbon	Medium

Slow Progression	Price scenario
Baseload electricity	Medium
Gas NBP	High
Coal ARA	Low
Carbon	Medium

Chapter four

Energy demand

Power demand

Gas demand

Residential demand

Industrial and commercial demand

Transport

Energy demand

4.1
Energy demand

In Gone Green and Slow Progression scenarios we see a reduction in overall energy demand despite the growth in population. This reduction is a result of society having 'greener' ambitions and changing its energy consumption behaviour. Gone Green, where the economy is more robust, sees a far greater likelihood of making the changes needed to achieve the government's carbon reduction targets. Consequently its overall energy demand is the lowest. It is the only scenario where these targets are met.

No Progression and Consumer Power, both lacking this green ambition, see an increase in overall energy demand, mainly as a result of there being more people and more homes requiring more energy.

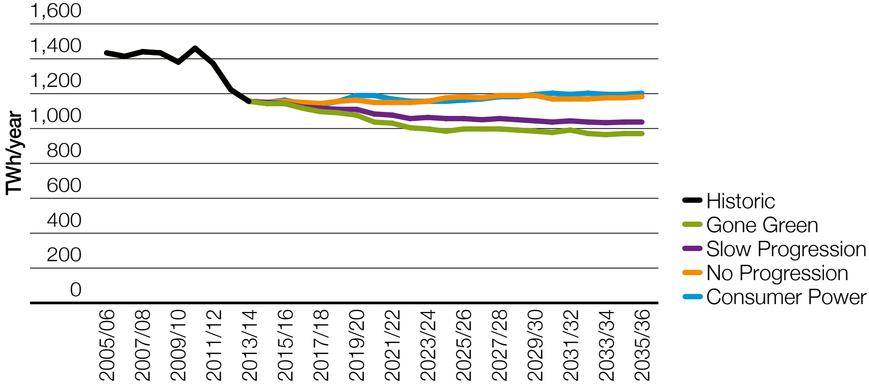
Key statistics

- Total annual energy demand across our scenarios is between 975 and 1,210 TWh/year by 2035, from a demand of 1,150 TWh/year today.
- Energy savings are achieved through the electrification of heat and continued improvements in energy efficiency in **Gone Green** – this leads to 40% of GB's energy use from power, up from 30% today.
- **Consumer Power** energy demand grows as a result of increased use of CHP shifting some of the power generation capabilities to the consumer site, increasing on-site gas demand by 30 TWh/year by 2035.

975 TWh

Total annual energy demand across our scenarios is between 975 and 1,210 TWh/year by 2035, from a demand of 1,150 TWh/year today

Figure 9
Energy: annual demand



We define energy demand, in this document, as the combination of gas and power demand across the residential, commercial, industrial, power generation and transport sectors. We do not consider energy from the conventional transport sectors, e.g. petrol or diesel vehicles, as petroleum products are not within the remit of National Grid.

A more detailed breakdown of the causes and effects for the residential, commercial, industrial and transport energy demands will be given later in this chapter, each in their subsections. The two key assumptions common to all our scenarios that influence overall energy demand are population and housing numbers. We use the economic and demographic forecasts by Experian Business Strategies to form the basis of our population growth and housing developments. We assume that the population of Great Britain reaches 71 million and that the number of homes grows to 32 million by 2035 in all of our scenarios. These compare with the population of 63 million and 27 million homes today.

With the same population and home projections, the different energy demands between our scenarios are mainly influenced by:

- economic growth and the implications on commercial and industrial demand
- demand from more appliances
- differing regulations that drive the rates of energy efficiency gains
- adoption of new technologies that displace existing appliances, such as the electrification of heat and transport
- adoption of on-site generation that influences demand for primary fuels such as gas micro-CHP.

Energy demand

4.1.1
Annual energy demand

The residential sector accounts for approximately 40% of today's energy demand. Future residential demand will fall in each scenario due to the electrification of heating with heat pumps and the continued efficiency gains in electrical appliances and lighting. Gas demand will be further reduced from improvements in insulation measures. The fall is most pronounced in **Gone Green** as this has the greatest take up of electric heating.

The industrial and commercial sectors account for approximately 50% of today's energy demand. Future demand will fall in three of the scenarios due to continued industrial decline and broadly flat commercial demand. The exception is **Consumer Power** where a switch in the commercial sector to on-site generation, predominantly micro-CHP, increases the demand for gas.

Across the transport sector demand increases in each of the scenarios, as the number of electric and gas vehicles increases. There is also a continuation of the electrification of rail transport.

The remaining 10% of energy is gas used for power generation – this is examined in more detail in Chapter 5, Power Supply.

This chapter differs in structure from the others within FES as the gas and power demands have been integrated. This approach has been adopted to enable you to better appreciate how the different sectors contribute to the whole energy requirement and how power and gas interact with each other at the sector level. As you progress through the chapter the detail will become granular. The first part takes a holistic view of energy demand, and is followed by separate overviews of the gas and power demands. Finally, the four sectors of residential, industrial, commercial and transport are addressed in detail as combined gas and power demands.

Power demand

4.2
Power demand

In each scenario total annual demand initially falls before rising to a higher level than today. When these variations occur, and to what extent, are dependent on the various factors affecting each scenario. The more prosperous economy in Gone Green and Consumer Power will lead to a noticeable increase in demand by 2035. Conversely, a weaker economy will produce only marginal increases in demand by 2035.

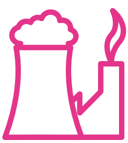
In general for all scenarios, residential demand rises, industrial demand reduces and commercial demand remains relatively flat.

Key statistics

- The current annual power demand is 339TWh/year
- By 2035/36 annual power demand ranges between 385TWh/year in **Gone Green** and 340TWh/year in **Slow Progression**
- The current peak demand is 60GW
- By 2035/36 peak demand ranges between 70GW in **Gone Green** and 61GW in **Slow Progression**.

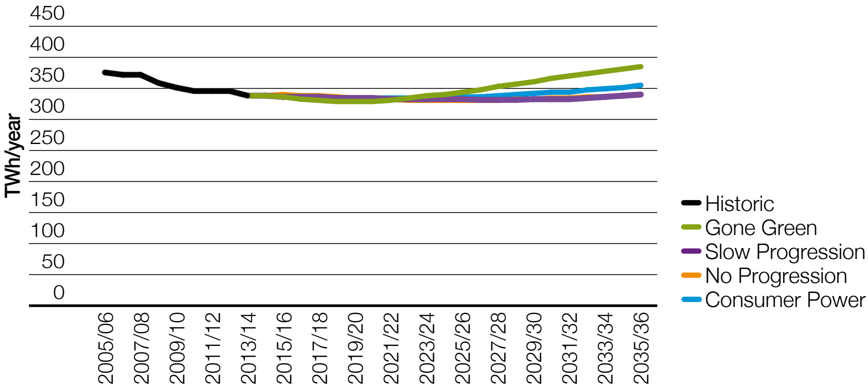
339 TWh

The current annual power demand is 339TWh/year



Power demand

Figure 10
Power: annual demand (including losses)



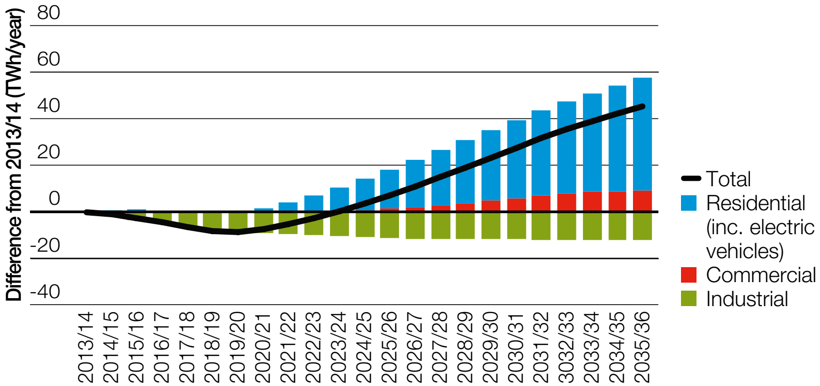
4.2.1 Results – Gone Green

Our **Gone Green** scenario (see Figure 11) experiences the greatest change in annual demand by comparison with today. Demand drops 9TWh/year by 2019/20 and then rises by 45TWh/year, to a total of 385TWh/year by 2035/36.

The initial dip is caused by a reducing industrial demand, which will continue to decline throughout the period, and is only partially offset by growth in the commercial sector. The residential sector remains flat due to a drop in demand for lighting, resulting from the adoption of LEDs, which is countered by a demand increase from the general growth in the number of households.

However, post 2020 we will see the start of the mass adoption of low carbon heating technologies and electric vehicles in the residential sector. The take up of these technologies causes demand to grow through 2035/36 and beyond. This is driven predominantly by incentives, offered as a result of a strong green ambition and an increase in prosperity.

Figure 11
Power: selected Gone Green power demand comparison to 2013/14 by type (excluding losses)



We believe that for environmental targets to be met beyond 2020, both transport and heating will have to be further incentivised away from conventional sources towards high efficiency electrified heat and transport which will run on electricity that has been largely decarbonised. This move to the electrification of heat will also depress the residential gas demand.

Power demand

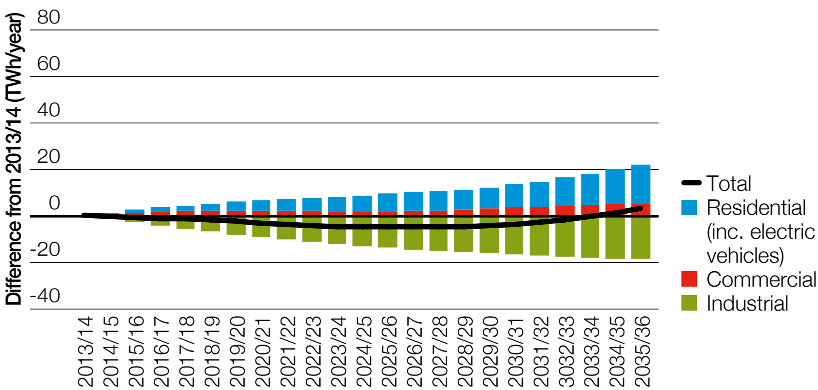
4.2.2 Results – Slow Progression

In **Slow Progression** (see Figure 12), without a prosperous backdrop there will be less demand growth. There will be limited money available to enable encouragement of green activities. Therefore, the uptake of electric vehicles and other low carbon technologies will be muted.

Residential demand will continue to grow as the number of households increases year on year.

Commercial demand will experience a slow growth over the period and only result in marginal additional requirements. This growth will be offset by a decline in industrial demand. The total annual demand will be below today's value until 2035/36.

Figure 12
Power: selected Slow Progression power demand comparison to 2013/14 by type (excluding losses)



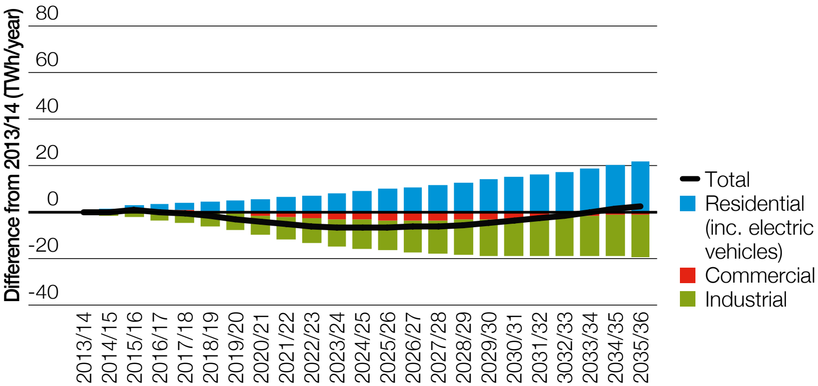
4.2.3
Results – No Progression

In **No Progression** (see Figure 13), with low prosperity and low green ambition, there is limited money or desire to spend money on energy efficient goods. As with all the other scenarios the increased demand from the residential sector is driven mainly by the increase in the housing stock, which rises continuously throughout the scenario.

With a lower green ambition and weaker economic growth there will be limited resources available to incentivise green activity via subsidies or other financial rewards. Therefore growth in electric vehicles and low carbon technologies will be less pronounced than in the more green scenarios. Electric vehicles will be relatively expensive and any take up of heat pumps will be minimal.

In a low prosperity world, commercial and industrial power demands will decline. The low level of green ambition will mean that commercial parties are likely to prefer gas, over power, for their heating requirements, as this will be relatively cheap. Industry's power demand will decline throughout the period.

Figure 13
Power: selected No Progression power demand comparison to 2013/14 by type (excluding losses)



Power demand

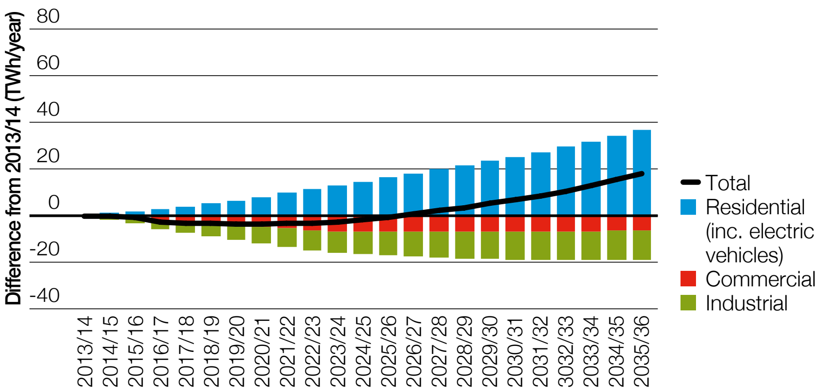
4.2.4
Results – Consumer Power

In **Consumer Power** (see Figure 14), there is a more prosperous society but less green ambition. This results in moderately strong growth in demand from the residential sector, caused by the increase in the housing stock and an increased uptake of desirable goods such as larger appliances and electric vehicles.

In the commercial sector, there will be more focus on gas heating rather than electricity, primarily due to the relative costs of gas and electricity.

The industrial sector's demand will decline throughout the period.

Figure 14
Power: selected Consumer Power power demand comparison to 2013/14 by type (excluding losses)

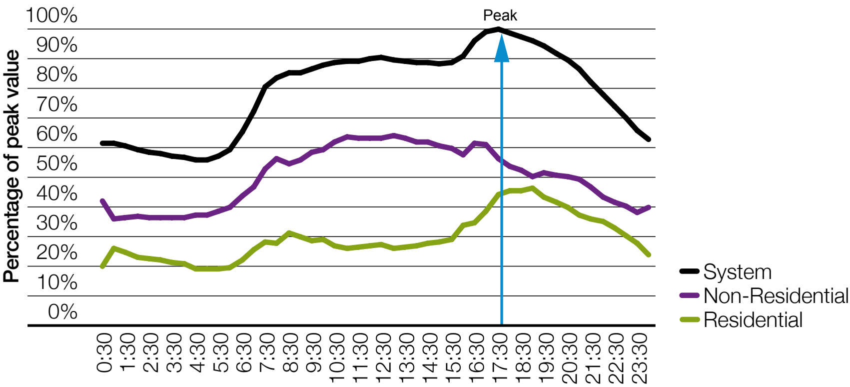


4.2.5
Peaks

Peak demand typically occurs at around 17:30hrs on a weekday between December and February. It comprises a declining industrial and commercial demand profile, when businesses are closing, and a rising residential demand profile, when people are returning home (see Figure 15). As this occurs in winter the dark conditions mean lighting demand is high and the less clement weather leads to a higher heating demand.

Both industrial and commercial demand side response (DSR), as well as residential time of use tariffs (TOUTs) will have a reducing effect on peak demand to a greater or lesser extent depending on the scenario. An explanation of DSR is given in the Industrial Demand section 4.5.4 and an explanation of TOUTs is given in the Residential Demand, Peaks section 4.4.5.

Figure 15
Power: typical peak hour demand



Power demand

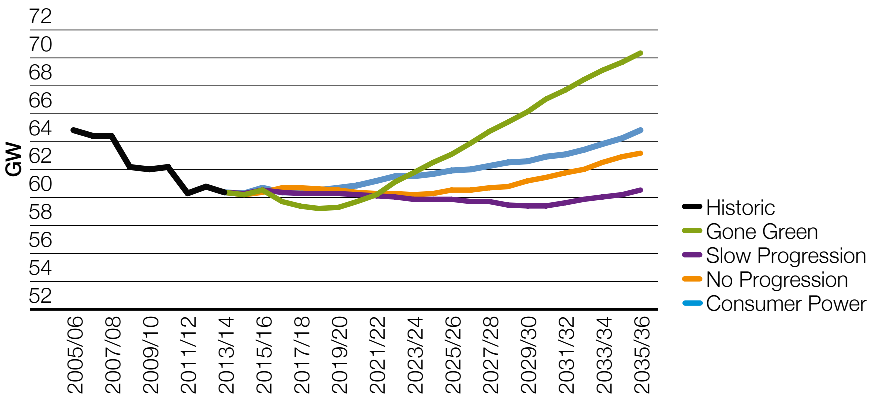
The peak demand profiles are closely related to the annual demand curves. The peak is a half hour snap shot of part of the annual demand, therefore they are quite similar in appearance.

The peak profiles (see Figure 16) that are least like their annual demand profiles are **Slow Progression** and **No Progression**. Their annual demands are very similar to each other but their peak profiles are not. The causes for this separation are the existence in **Slow Progression**, and less so in **No Progression**, of mechanisms which encourage responsiveness and limits demand during the peak period. These mechanisms are primarily residential TOUTs, and industrial and commercial DSR.

Gone Green also has these limiting mechanisms, but they are offset by the incentive-driven growth in heat pumps, which are likely to be used during peak time.

Consumer Power has these mechanisms to reduce its peak demand; however demand rises from more appliances which will exist in a more prosperous economy.

Figure 16
Power: average cold spell peak demand (including losses)



Method

We have chosen the following definition of demand as it provides a clear distinction between supply and demand. We do not consider any reduction of demand by any form of generation. Annual power demand used in this document is:

"The weather corrected demand[1] from residential, commercial and industrial consumers and transmission and distribution losses: power generation from distributed generation and micro-generation has not been deducted."

It does not include exports, or imports, to or from Ireland and the continent (please refer to section 5.2), station demand[2] or pump demand[3]. This definition has been chosen because FES is attempting to assess the underlying GB demand requirement.

Micro-generation and distributed generation are considered as supply, and do not reduce the demands thus differentiating between supply and demand. Station demand and pumped storage demand are not included but are taken away from the gross generation output; thus aligning with national demand.

We take National Grid's fiscal year weather corrected transmission demands and derive the underlying demand by adding our estimates of distributed and micro-generation output. We then calculate residential, industrial and commercial demand using other sources including Elexon and DECC's Energy Consumption in the UK and Digest of UK Energy Statistics.

In FES 2015 when we illustrate residential, industrial and commercial components we have not assigned the distribution or transmission losses. These are network losses and it is not appropriate to include them at the sector level. The network loses have been included in the total annual and peak demands. These losses, we estimate, to average around 6% for distribution and 2% for transmission, totalling 7% of annual demand.

Peak demand is the maximum demand on the system in any given financial year. Having created annual demands, we then calculate and calibrate the average cold spell (ACS[4]) peak demands. Peak demand is then aligned to National Grid's ACS history and operational ACS forecasts for winter 2014/15 and winter 2015/16.

In order to make longer term ACS peak projections from annual demand we apply a recent historical relationship of annual to peak demand. This creates an initial peak demand, to which we add components that we feel history cannot predict, such as electric vehicles, heat pumps, TOUTS and DSR.

[1] This is the actual demand figure that has been adjusted to take account of the difference between the actual weather and the seasonal normal weather.

[2] Station demand is the onsite power station requirement, for example for systems or start up.

[3] Pumping demand is the power required to fill hydro reservoirs.

[4] ACS is defined as a particular combination of weather elements which gives rise to a level of peak demand within a financial year which has a 50% chance of being exceeded as a result of weather variation alone.

Gas demand

4.3
Gas demand

Historical gas demand decline in GB is set to continue in Slow Progression and Gone Green, which see further efficiency improvements and an uptake of alternative heating appliances. Consumer Power and No Progression see increased demand from a lower energy efficiency drive, combined with growth in the power station and distributed gas CHP sectors.

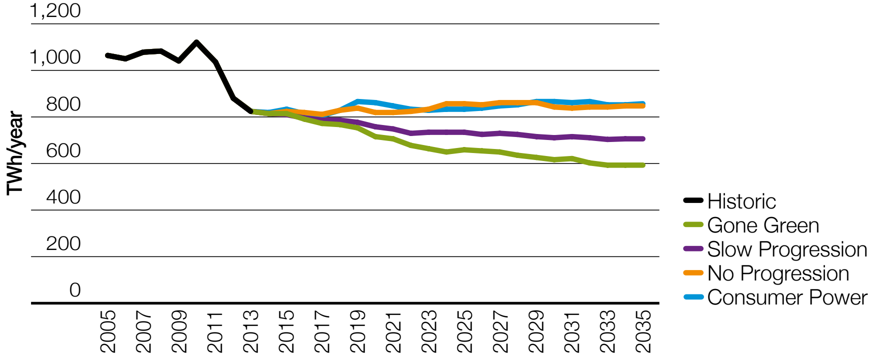
Key statistics

- Demand in **Gone Green** falls by 250 TWh/year below today's demand by 2035
- In **Consumer Power**, gas demand increases by 40 TWh/year in 2030 compared to 2013, largely from industrial and commercial growth

250 TWh

Demand in **Gone Green** falls by 250 TWh/year below today's demand by 2035

Figure 17
Gas: total annual demand



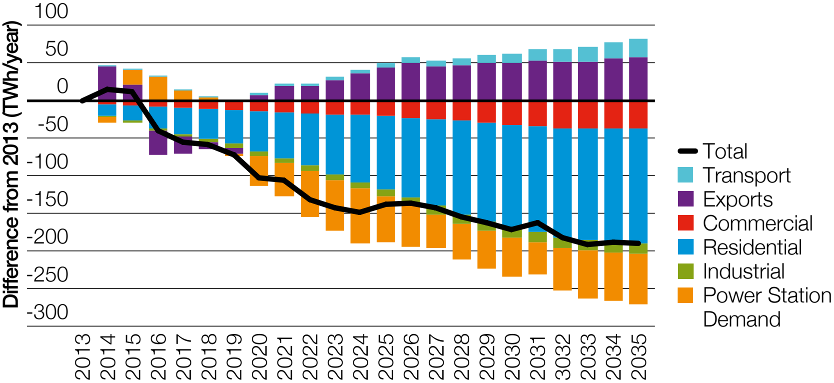
4.3.1
Results – Gone Green

Gas demand in **Gone Green** reduces sharply, led by residential demand. This is due to a high roll out of insulation, the replacement of old boilers with new, A-rated efficient ones, the introduction of smart controls, progressive building regulations for new homes and the displacement of gas through electrification of heating.

Similarly, commercial properties are encouraged to install heat pumps to benefit from low carbon heating sources. The switch to alternative heating significantly reduces the demand for gas across residential and commercial buildings. We have assumed that the Renewable Heat Incentive (RHI) or an alternative mechanism remains in place driving the uptake in low carbon heating, providing economic backing to an otherwise uneconomical choice. Renewable generation displaces gas power over time, which reduces demand from combined cycle gas turbines (CCGT).

Gas demand

Figure 18
Gas: Selected[1] Gone Green demand comparison to 2013 by type



4.3.2
Results – Slow Progression

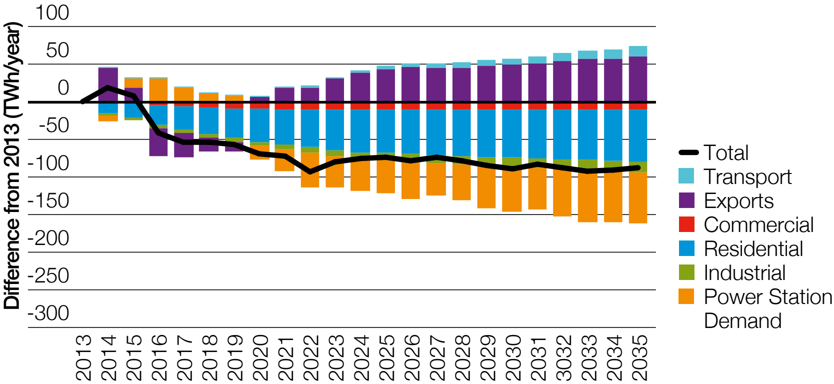
Slow Progression has similar trends to **Gone Green** with less favourable economic conditions. The support for heat pumps isn't on the same scale as **Gone Green** and capital cost reductions do not materialise. Gas demand remains high in the residential sector with a lower uptake of alternative heating appliances, but demand still declines as a result of improved thermal efficiencies and new boilers.

Developments in renewable power generation lead to lower CCGT generation demands over time. However the timescales are later than in **Gone Green**.

[1] Selected key demand sectors e.g. not including shrinkage

Chapter four

Figure 19
Gas: Selected Slow Progression demand comparison to 2013 by type



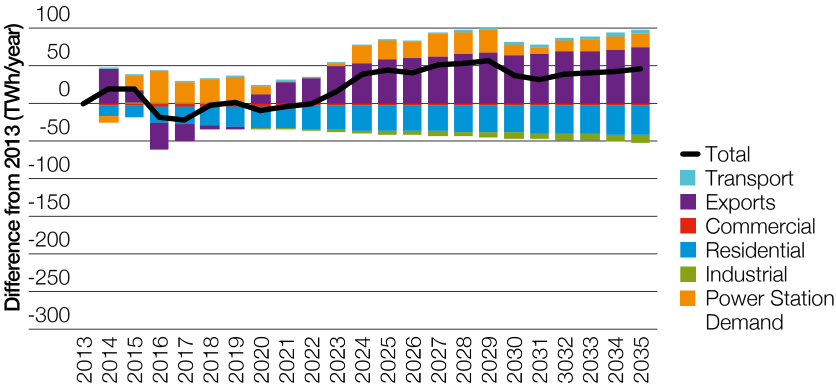
4.3.3
Results – No Progression

The **No Progression** world favours gas as an energy solution requiring additional gas for power generation. Residential demand falls mainly from the uptake of A-rated gas boilers, but the fall is less pronounced than in **Gone Green** or **Slow Progression**. This is because less insulation is installed and the ambition for a green economy is scaled back.

Industrial demand for gas continues to decline, as the economy grows at a slower rate, while commercial demands remain flat. Additional demand from power stations and the increase in gas demand for exports to Ireland offset efficiency savings in the residential market.

Gas demand

Figure 20
Gas: Selected No Progression demand comparison to 2013 by type



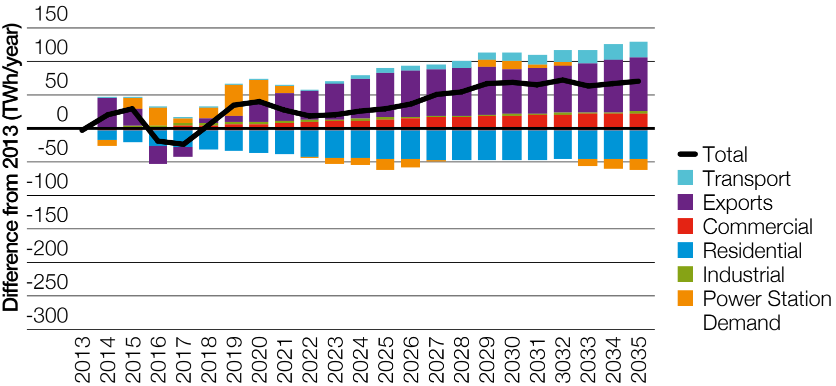
4.3.4 Results – Consumer Power

Gas demand for power generation remains fairly flat in **Consumer Power**. Retail gas prices are lowest in this scenario leading to significant investment into distributed renewable and combined heat and power (CHP) generation. The investment in distributed generation reduces the need for CCGTs pushing some power generation downstream from the network and into customer properties.

Residential customers continue heating their homes with gas and start to access new technologies to take advantage of the price spread between power and gas. Micro-CHP and fuel cells become commercially viable, boosting gas demands and offsetting some of the efficiency improvements associated with buildings and appliances.

Commercial demand grows in **Consumer Power** due to fuel switching from power to gas and installation of gas CHP. Heating for commercial buildings moves away from electricity to benefit from relatively lower retail gas prices and CHP provides economical on-site power production. Gas vehicles start to replace diesel HGVs.

Figure 21
Gas: Selected Consumer Power demand comparison to 2013 by type



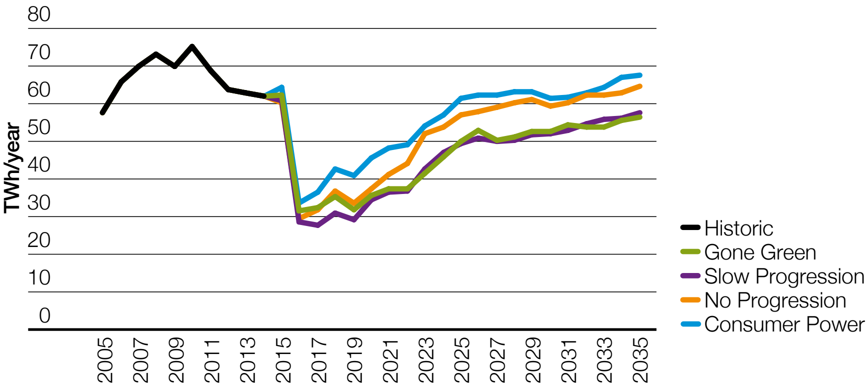
4.3.5
Ireland and Europe

The level of gas exports to Ireland is highly influenced by the timing and scale of supply from indigenous Irish supplies. We have assumed that the Corrib gas field starts operation in October 2015 with a step change in production rates from March 2016. We have assumed that Corrib will reduce the exports from Great Britain. However, we also assume the field is relatively short lived with production rates reducing over time and the reliance on exports gradually returning.

Our scenarios for Ireland and Europe include underlying energy demand growth related with higher economic growth in **Gone Green** and **Consumer Power** and lower growth in **No Progression** and **Slow Progression**. We have aligned higher development in renewable generation to **Gone Green** or **Slow Progression** and slower developments with higher gas demand for power generation in **Consumer Power** and **No Progression**. Our scenarios are developed by taking the underlying demands for residential and industrial demands from the Network Development Plan prepared by Gaslink, the Irish gas system operator. Gas demand for power generation was flexed in line with the submissions of the Northern Ireland and Irish electricity transmission system operators SONI and EirGrid to the ENTSO-E ten year network development plan.

Gas demand

Figure 22
Gas: demand from the National Transmission System to Ireland



Flows to and from Europe via interconnector UK (IUK) is sensitive to both UK and continental gas supply/demand balances. As described in the Gas Supply section in chapter 5, the level of imports from the continent and liquefied natural gas (LNG) are interrelated and subject to uncertainty. We provide more detail on the impact of exports and imports in the Gas Supply section.

4.3.6
Peaks

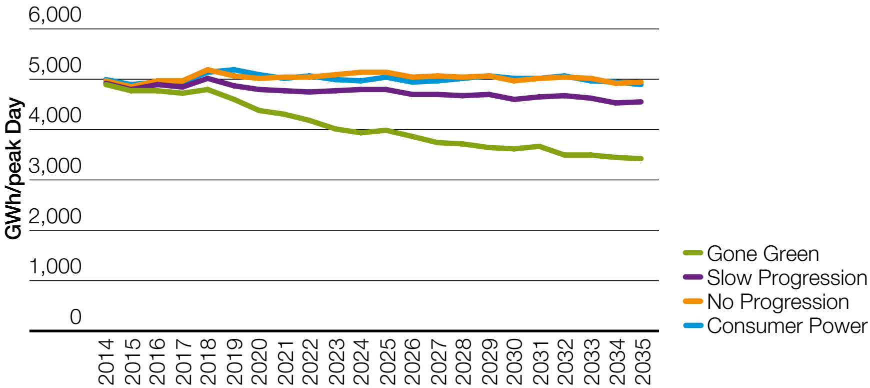
The 1-in-20 peak gas demand is based on a historical relationship between daily gas demand and weather combined with the amount of gas power station demand expected on a peak day.

The relationship between the peak day demand and weather is periodically reviewed and during 2014/15 we adopted the industry standard demand to weather relationships that take effect from October 2015 (see Method). Peak gas-fired electricity generation is less related to weather and more dependent on assumptions about generation availability and the position of gas-fired power generation within the generation order.

Unlike annual gas demand for power generation, the peaks in **Slow Progression**, **No Progression** and **Consumer Power** remain broadly in line with recent history, due to the increasing requirement for gas-fired power generation to act as a back-up for renewable generation. In **Gone Green** the peak gas demand decreases primarily as a consequence of reduced residential demand.

Figure 23 shows the peak demands for all four scenarios. The difference in peaks reflects the differing assumptions in residential and commercial annual demands and level of dependence on gas-fired generation.

Figure 23
Gas: peak demand



Gas demand

Method

Peak gas demands are based on the relationship between gas demand and weather, in the form of a composite weather variable (CWV), which includes temperature and wind-chill. Approximately every 5 years the CWV is re-optimised to ensure that the relationship remains valid. During the latest re-optimisation[2], a new weather dataset was introduced to coincide with the introduction of a formal weather station substitution methodology which is outlined in the Uniform Network Code. The new weather dataset has also been adjusted for the effect of climate change. Our peak demands in Figure 23 make use of this new climate adjusted weather, and as such are lower than in previous years' analysis. Peak day demand at local distribution zone level has subsequently fallen by 7% on average as a result of the updated method.

This year we have separated the Industrial and Commercial demands by sub-sector from their economic definitions. These do not map directly onto the gas load bands 72–732 MWh/year and >732 MWh/year. As such we have used an indexed growth method to map across while keeping the net demands constant between the two load bands.

[2] CWV Approach Document: gasgovernance.co.uk/desc/250314

Residential demand

4.4 Residential demand

GB residential energy demand is intrinsically linked to the number of homes in Great Britain. Heating, which dominates residential energy demand, is falling as a result of increased insulation and more efficient boilers. In Gone Green we expect a shift to more electrical heating in the form of heat pumps.

Residential power demand grows consistently due to a continued growth in the number of homes and population, which will require basic appliances such as refrigerators, cookers, audio visual appliances, etc. There is a more rapid growth in the number of electrical goods such as telecoms, tumble dryers and dishwashers.

Key statistics

- Homes with electric heating grow in **Gone Green** from 2 million today to 8.7 million in 2035
- Homes with micro-generation heating appliances grow from 1,200 appliances today to 2.7 million in 2035 in **Consumer Power**
- Annual power demand (including electric vehicles) increases from today's 110 TWh/year to 157 TWh/year in **Gone Green** and 127 TWh/year in **Slow Progression** by 2035
- Annual gas demand falls from today's 321 TWh/year to 296 TWh/year in **No Progression** and to 183 TWh/year in **Gone Green** by 2035

110 TWh

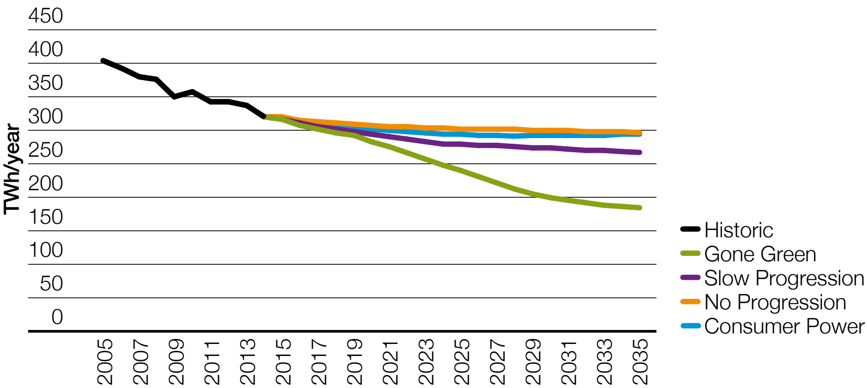
Annual power demand (including electric vehicles) increases from today's 110 TWh/year to 157 TWh/year in **Gone Green** and 127 TWh/year in **Slow Progression** by 2035

Residential demand

In **Gone Green** and **Slow Progression** the energy-hungry halogen light bulb will fall out of use by 2035. In **Gone Green** they are replaced by LEDs. In **Slow Progression** they are replaced by a mixture of LEDs and compact fluorescent light bulbs. Halogens will survive in **Consumer Power** and **No Progression**.

Time of use tariffs will become available within all the scenarios. The take up and the associated peak time savings will vary across the scenarios. **Gone Green**, which produces the most saving in 2035, will have a peak reduction of 3.7GW, whereas **No Progression**, which will produce the least savings, will achieve only 0.3GW.

Figure 24
Gas: annual residential demand



Residential gas demand is driven by the heating demand in homes. This in turn is affected by the thermal efficiency of the building (insulation), efficiency of the boiler or other heating appliance, and the temperature of the property.

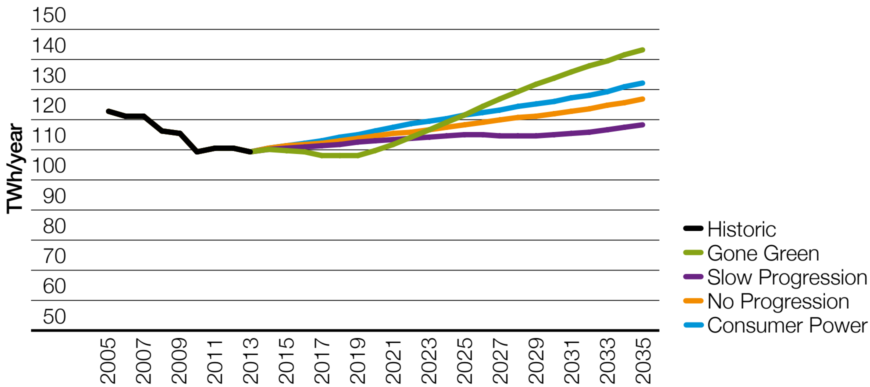
In **Gone Green** around 10 million homes install low carbon heating technologies (LCHT) by 2035, including, air source heat pumps (ASHP), ground source heat pumps (GSHP), hybrid heat pumps, micro combined heat and power (mCHP), and biomass. This causes a decline in gas demand of around 140TWh/year from today's levels (321TWh/year).

Slow Progression has a slow decline with LCHT still replacing gas boilers, but at a much slower rate than in **Gone Green**. Gas demand is reduced by the higher levels of insulation installation.

No Progression has the least efficiency gains from boiler replacements and insulation.

Consumer Power has higher efficiency gains from insulation and boiler replacements. However, the LCHT installed are gas focused (mCHP and fuel cells) which sustains a level of gas demand for this scenario.

Figure 25
Power: annual residential demand (excluding electric vehicles and losses)



The power demand in **Slow Progression**, **No Progression** and **Consumer Power** all experience steady rises from today's level. These increases are driven by an underlying increase in the number of households with their associated requirements for power consuming products. In addition, there are increased power demand requirements from appliances, heating and hot water in established homes. These increases are tempered by an overall drop in demand from lighting as a result of a growth in installations of more efficient LEDs.

In order for government carbon reduction ambitions to be met, low carbon heat sources, such as heat pumps, will have to significantly increase their numbers. This is only likely to occur if effective incentives or regulations are introduced.

Gone Green has a different trend in comparison with the other three scenarios. After an initial sharper reduction, it adopts a steeper increase in its power demand requirement. The decline is a result of the widespread adoption of LEDs. They rapidly replace halogen bulbs as a result of policy implementation and the higher price of electricity. However, post 2020, there will be a steep rise in the power demand requirements for space heating as a result of a significant rise in the deployment of heat pumps. This is as a result of government incentives promoting heat pumps in order to decarbonise the economy. There will be a proportional drop in gas demand for heating purposes.

Residential demand

4.4.1
Results – heating and air conditioning

Heat is currently responsible for 8% of total electricity demand and 28% of gas demand. Changes in heat demand, such as the introduction of new technologies and improved efficiencies, have a substantial impact on overall gas and electricity consumption.

The introduction of new heating technologies could displace the traditional gas boiler; this effect is mainly reflected in **Gone Green**. Figure 26 illustrates how the gas boiler's market dominance falls from 85% to 55% by 2035 as technologies such as heat pumps and biomass boilers grow. This has a large impact on both gas demand – the offset gas boilers – and power demand, as most of the LCHT are ASHP.

Figure 26
Residential heating technologies in Gone Green

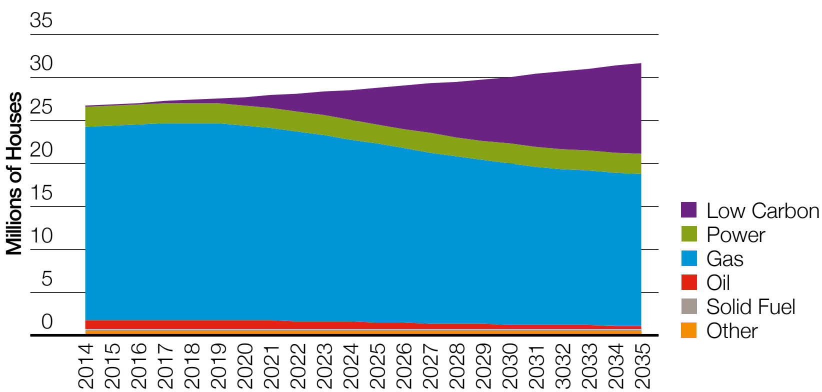
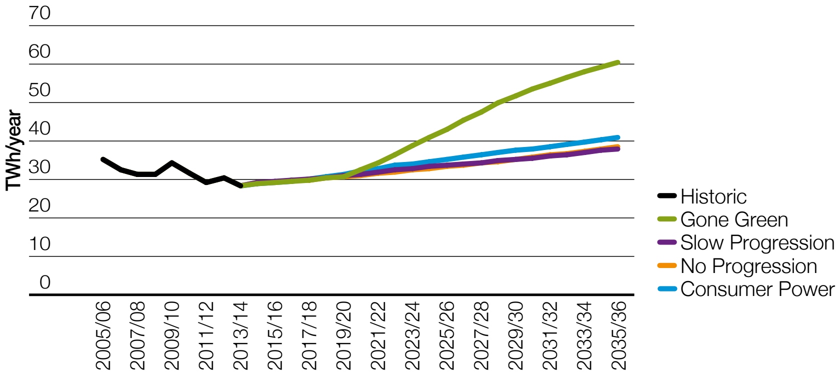


Figure 27
Power: annual residential heating demand (including air conditioning) (excluding losses)



With the exception of **Gone Green**, power demand for the residential sector experiences a steady and slow rise over the period. This is driven mainly by the increases in the housing stock and population. The major component of the electrical heating profiles is space heating, which represented 73% of the total in 2014. Consequently, the variations in our power demand trajectories can be explained by a combination of a slowly rising resistive heating and LCHT demands. However, the LCHT with the largest market share, in all of our scenarios, is ASHP; their take up significantly influences the **Gone Green** projection.

In **Gone Green**, there will be significant government drive to promote heat pump deployment. This situation is mirrored in the commercial sector (see section 4.6).

In this year's analysis we have assumed a less aggressive demand from heat pumps, in all scenarios, as a result of feedback from stakeholders. We have also adopted a new modelling approach that fully considers the costs and technology selection by household segments. This enables us to make adjustments for consumer and market behaviours.

Residential demand

Insulation

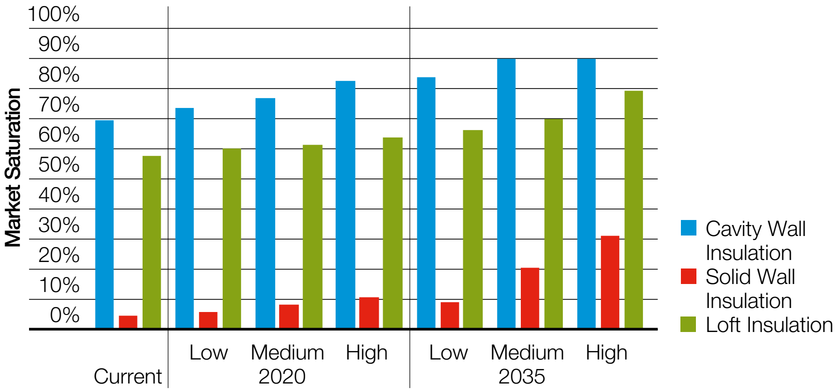
Government insulation figures show that the markets for cavity wall and loft insulation are starting to saturate. Most of the easy to install installations were completed under the Carbon Emissions Reduction Target (CERT), Community Energy Saving Programme (CESP) and Warm Front schemes which closed in 2012. By the end of 2013, approximately 60% and 70% of the potential installations of loft and cavity wall insulation respectively had been installed. There is, therefore, less room for further growth in these markets, in stark contrast to that of solid wall insulation.

There remains a significant potential for solid wall insulation but to date the high cost has resulted in a low uptake, as seen in Figure 28. Only 4% of potential installations were completed by the end of 2013. However, during 2014 installations of solid wall insulation increased significantly following the release of the Green Deal Home Improvement Fund (GDHIF). The fund paid over £35m for solid wall insulation in 2014, and more funding has been allocated for future installations.

Government figures show there are over seven million solid walled homes without solid wall insulation. To insulate all of these homes through the current funding scheme would cost between £20bn and £30bn.

Figure 28 shows the current level of market penetration of the three insulation types, along with the range of possible outcomes in 2020 and 2035. **Gone Green** contains the high case for solid wall, cavity wall and loft insulation, while **No Progression** has the low case for all three. In **Slow Progression** we assume high cases for cavity wall and loft insulation while solid wall insulation is at the medium rate due to the higher costs and less capital being available. **Consumer Power** has the medium cases of cavity wall and loft insulation and the low case of solid wall insulation. This is due to solid wall insulation being relatively expensive and considered lower in priority with a weaker green ambition.

Figure 28
Insulation uptake ranges



The rapid uptake of the GDHIF has shown that there is consumer appetite for insulation. In order for there to be a continued high uptake, funding schemes need to continue beyond 2017. Additionally, high levels of support such as the GDHIF need to be offered to incentivise home owners to install solid wall insulation.

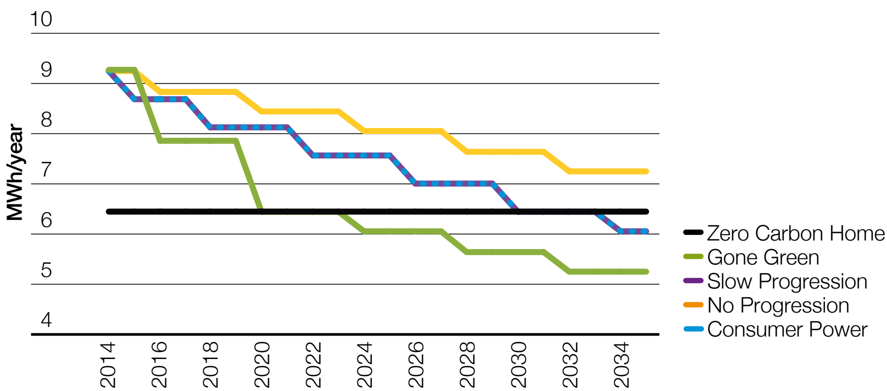
Residential demand

New builds

Stakeholders have told us that the pace of change to building regulations in our 2014 analysis was too rapid. In response, we have adjusted our assumptions to progress towards the Zero Carbon Home[1] standard as opposed to the more stringent Passivhaus[2] standard. We assume that historic trends continue such that building regulations are adjusted and adopted every four years creating a step change. We have held the average demand for hot water constant at 2.5MWh per year as per feedback from stakeholders.

The date by which new homes are built to the Zero Carbon Homes standard differs between the scenarios, as seen in Figure 29. In **Gone Green**, homes meet the target in 2020 as there is both the money and government drive to encourage this. In **Slow Progression** and **Consumer Power** progress is slower, reaching the standard in 2030. **No Progression** has the slowest rate of change, reaching the standard in 2040. With an average build rate of 210,000 domestic homes per year, building to the Zero Carbon Homes standard in contrast to today's average new property saves 590GWh of thermal energy demand per year. The overall heat demand saving resulting from reaching this standard in 2020 rather than 2040 is over 10TWh/year.

Figure 29
Heat demand for an average new home



[1] www.zerocarbonhub.org
[2] www.passivhaus.org.uk

Internal temperature

Increases in average internal temperatures causes increases in heat demand. As such we have assumed that in **Gone Green** and **Slow Progression** average internal temperatures do not increase beyond today's level due to the social engagement and ambition to reduce emissions.

In **Consumer Power**, temperatures are assumed to rise at the highest rate consistent with higher levels of disposable income, to a maximum cap of two degrees.

No Progression is also assumed to see temperatures increase, but is capped at a one degree increase. Both of these caps are in line with stakeholder feedback.

A one degree change in internal temperatures results in a 1% to 3% change in heat demand. Therefore, by 2035 internal temperatures could account for a difference of up to 12 TWh/year of thermal demand between **Gone Green** and **Consumer Power**.

Internal temperatures are affected by consumers' real and perceived disposable incomes, and energy prices. As higher temperatures become more affordable the average temperature is likely to increase (up to a limit) unless social attitudes to energy consumption changes to produce different behaviour.

Residential demand

Smart thermostats

A smart thermostat is a device which allows consumers to remotely control their boiler thermostats via the 'cloud'.

The UK market for smart thermostats has taken off rapidly in the past few years. Estimates suggest that there are between 200,000 and 400,000 devices currently in the UK market. Thermostat companies, technology firms and energy companies are offering the devices at a relatively low cost to consumers as an energy saving device.

Customers who buy smart thermostats in **Gone Green** and **Slow Progression** experience a higher impact on their energy demands than in **Consumer Power** and **No Progression**. They experience a 20% reduction compared to 10% in the other two scenarios. This is a result of the types of technologies adopted and how they are used.

In the greener scenarios, residents are engaged with reducing their energy demands, aiming to maintain the heat comfort in their home but in a more efficient way, reducing wasted heat. However, in **Consumer Power** and **No Progression**, the technology is also used to make life more comfortable in the home, such as warming the house in advance of it being occupied, so savings are reduced.

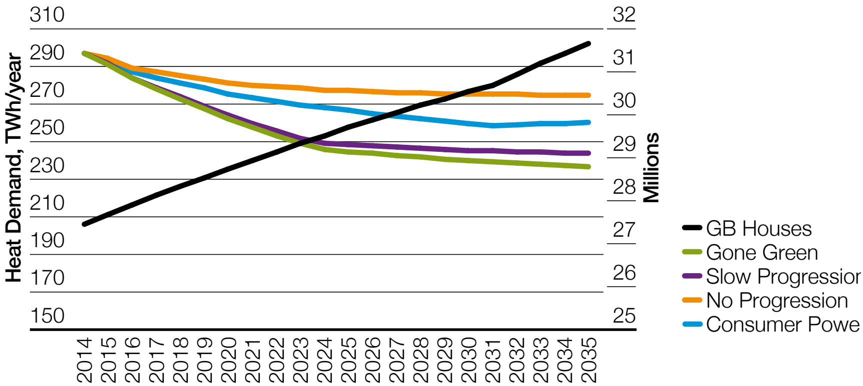
Our analysis has suggested that there is a potential to reduce current heat demand by 20TWh/year to 40TWh/year through installing smart thermostats. This would lower demand by 6% to 12%.

In order for smart thermostats to have a large market impact, consumers need to be engaged with home energy management. Additionally, actual energy and bill savings need to reflect the manufacturers' claims of 10% to 40%.

Traditional heating systems

Gas boilers dominate the current residential heating market, with approximately 85% of GB homes 'on gas' today. There are continued efficiencies to be made from replacing older boilers with new, more efficient models. We assume that 1 to 1.5 million 'A-rated' appliances are purchased each year in response to legislation in 2005, which ruled that the majority of new boilers must be of the most efficient level. The remaining populations of band B-G appliances decline throughout the period to 2035 to near-zero values. This creates the following overall gas demand savings in Figure 30; aggregating the impact of insulation, boiler replacements and new property demand reductions.

Figure 30
Gas: demand savings from insulation and boiler replacement



Chapter four

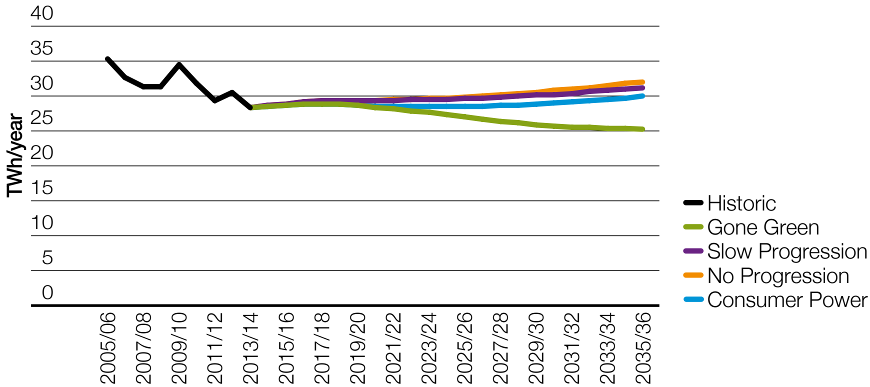
Residential demand

The electrical heating of rooms can be performed by either resistive means (bar heaters, storage heaters, etc.) or via LCHT (heat pumps, etc.).

There will be a general increase in demand associated with new build housing requirements. This increase will be tempered by the introduction of the newer technologies post-2017 and improved housing insulation. As shown in Figure 31, this dampening effect is more pronounced in both **Gone Green**, and, less so, in **Consumer Power** where incentives will not be available.

This dampening effect will be reduced further in **Slow Progression** and **No Progression** as we assume that there are lower energy efficiency gains in these scenarios, due to less money in the economy and thus driving down the demand for these technologies and inhibiting innovation.

Figure 31
Power: annual demand for residential resistive space heaters and hot water (excluding losses)



Low carbon heating technologies

We have defined a low carbon heating technology as one that has a lower carbon intensity for heating homes than an A-rated efficient gas boiler. Ground source and air source electric heat pumps, gas heat pump, hybrid heat pump, biomass, micro combined heat and power (mCHP) and fuel cells are examples of the technologies considered low carbon.

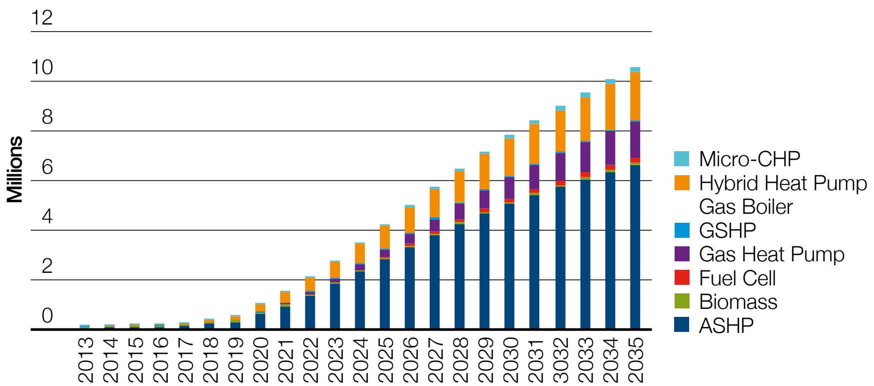
There are numerous factors affecting the decision to choose an alternative heating technology. The main drivers cost savings, reducing energy use or emissions.

Stakeholders told us that 79% of new builds have a gas connection, and we have adjusted our assumptions accordingly. However, the range and uptake of alternative technologies across both existing and new homes differs between the scenarios.

In our 2014 scenarios we assumed that alternative technologies would initially displace mainly non-gas appliances. Conversely, recent data and stakeholder feedback has shown that installations are displacing both gas and non-gas heating appliances, and we have adjusted our assumptions as a result.

The shift to low carbon heating in the residential sector requires continued government support. An incentive such as the Renewable Heat Incentive needs to continue into the long term to provide competitive prices compared to gas heating.

Figure 32
Installed low carbon heating technologies in Gone Green



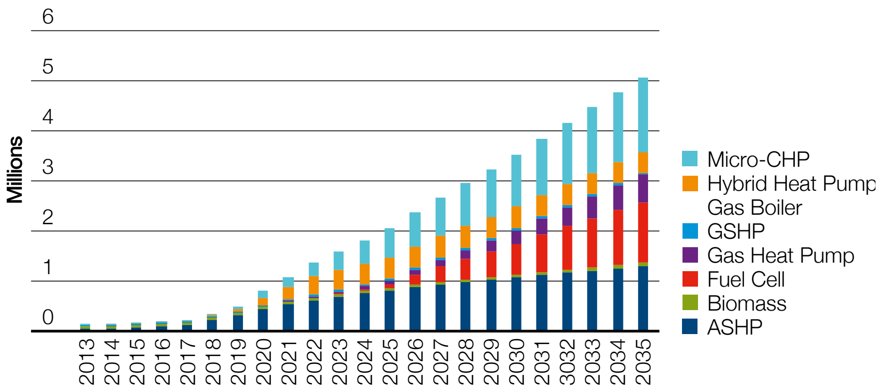
Residential demand

In **Gone Green** there are 10 million installed low carbon heating technologies in 2035, mostly air source, hybrid and gas heat pumps.

Consumer Power has the second highest shift, reaching five million alternative appliances by 2035. Due to the large difference between gas and electricity prices, there is a large uptake of mCHP units. The high level of research and development also supports fuel cells entering the market.

For our 2015 scenarios we commissioned a new modelling tool, which was built with the support of Delta-Energy and Environment. This is a step change on our previous modelling. It allows us to consider the GB housing stock as 22 different housing segments and to fit heating technologies into those homes based on economics, physical fit and soft factors like government push.

Figure 33
Installed low carbon heating technologies in Consumer Power



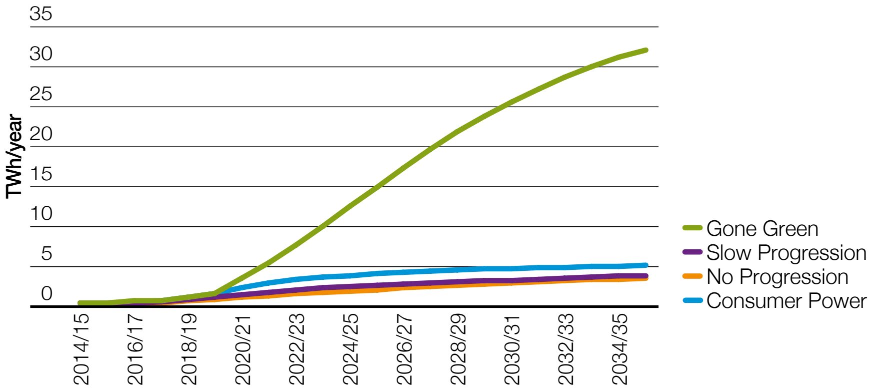
In both **Slow Progression** and **No Progression** there is much lower take up, reaching around two million alternative technologies by 2035.

In this year's modelling, our demand levels for all scenarios have increased. This is due to a combination of three factors. Firstly, we now believe that heat pumps will not be as efficient as we had previously thought as a result of an update to our market and technology research, thus heat pumps will draw more demand. Secondly, we have reassessed which types of homes are likely to install the projected number of heat pumps; we now believe that they will be larger homes which will require more heat than the average sized home, thus drawing more demand. Thirdly, homes that are currently heated electrically are a poor fit, economically, for retrofitting heat pumps: they would need to install a central heating system. Thus these homes sustain their resistive heat demand.

Slow Progression and **No Progression** will see a steady power demand rise due to new housing stock increases. As discussed at the start of this section, **Gone Green** will experience a dramatic rise in the deployment of newer technologies which we believe needs to be driven by incentives. **Consumer Power** has an initial increased use of newer technologies as they will be seen as desirable products and there will be the money available to spend.

The contribution of LCHT to peak power demand, by 2035, could be as much as 9.6GW in **Gone Green** and around 2GW in the other scenarios.

Figure 34
Power: annual demand for residential low carbon heating technologies (excluding losses)



Residential demand

Heat networks

Heat networks, also known as district heating systems, supply heat to a number of buildings from a central production facility through an insulated pipe system. They are typically built in high heat density areas such as city centres. Such systems currently supply approximately 200,000 residential homes in the UK, less than one percent of homes. As such, they have a very small impact on heat demand.
The government's long-term vision includes a larger role for heat networks. Expanding the role of heat networks has the potential to lower emissions at the point of use and could run from an efficient local source.

The development of heat networks remains unclear and is dependent on geographical factors. In 2015/16 we have commissioned Buro Happold to help us with our modelling. This will lead to dedicated research into the economic, regional resources and longer term potential heat sources that could unlock low carbon opportunities for district heating.

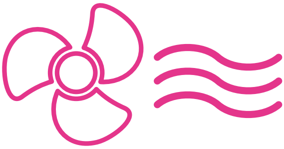
Gone Green has the highest uptake of heat networks due to having sufficient heating systems installed to drive the central heat production, and regulation guiding the building of systems. The systems are new CHP, particularly biomass CHP which is not driven by an on-site industrial or commercial building demand. There are around 1.4m residential connections by 2035, with a thermal demand of 12TWh/year in **Gone Green**.

No Progression has the lowest development with around 600,000 total homes connected by 2035, representing a thermal demand of 4TWh/year.

Our capacity and power outputs associated with CHP can be found in the Power Supply section in chapter 5. You can read more in the Future of Heat case study in chapter 7.

Air conditioning

This year, as a result of stakeholder feedback, we have modelled air conditioning. The power demand from air conditioning units sees a steady rise based on a slow increase in their adoption and the rise in the housing stock. In **Consumer Power**, we assume that the rate of increase is twice that of the other scenarios, rising from today's low base of 0.1 TWh/year to almost 6 TWh/year by 2035.



6 TWh

In **Consumer Power**, we assume that the rate of increase is twice that of the other scenarios, rising from today's low base of 0.1 TWh/year to almost 6 TWh/year by 2035.

Residential demand

4.4.2 Appliances

As a result of stakeholder feedback we have tempered our assumptions on the energy efficiency gains in **Gone Green**, **Slow Progression** and **Consumer Power** scenarios. We have retained the assumptions for **No Progression** as this scenario maintains its low efficiency gains.

Most of the appliance types modelled follow a similar trend within each of our scenarios, see Figure 35. In all scenarios we envisage a continued and steady growth in power demand from certain appliances i.e. cooking, wet and audio visual appliances. A more accelerated demand growth is seen from telecoms and other appliances, and also dishwashers and tumble dryers.

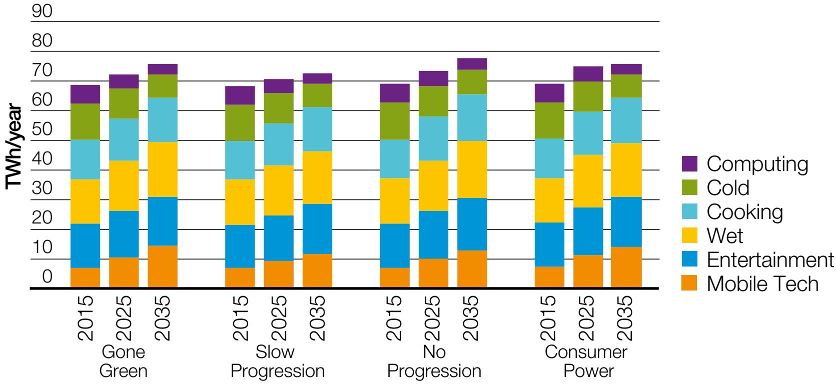
We also assume steady declines in the demand from refrigeration. In all the scenarios they have reached their saturation point in the current housing stock. Any increase in numbers, as a result of new housing, will be offset by continued efficiency gains of new appliances.

In all the scenarios computing demand falls. DECC data[1] for 2013 shows demand from computers declining after a period of slow down due to the falling numbers of desktops and the increasing efficiency of monitors and laptops. We continue this trend in our projections.

There are more appliances in **Gone Green** and **Consumer Power**, due to prosperity, than in **Slow Progression** and **No Progression**. We use lower energy efficiency assumptions in **No Progression** and **Consumer Power**, due to low green ambitions. This combination results in **No Progression** having the greatest demand followed by **Gone Green** and **Consumer Power**. **Slow Progression** has the least demand.

[1] Energy Consumption in the UK (ECUK) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/375388/domestic.xls

Figure 35
Power: annual demands for residential appliances by categories



Residential demand

4.4.3 Lighting

In all our scenarios there is a terminal decline in electricity demand from filament light bulbs and a decline in halogen bulbs depending on the scenario. In terms of bulb numbers LEDs become the dominant light source in all scenarios and they represent over half of all the bulbs in use by 2035. The overall effect is a decline in the demand from lighting.

In **Gone Green**, LEDs are adopted almost universally by 2030, driven by higher electricity prices, higher technological innovation, which will also drive down the units' price, and the legislative banning of selected halogen bulbs[3]. Compact fluorescent lights (CFL) will be eliminated in the more prosperous **Gone Green** and **Consumer Power** scenarios. The opposite environment will exist in **No Progression**, with its lower electricity prices, lower technological innovation and low policy drivers. This slows the LED development and adoption rate and, by default, prolongs halogen usage.

Slow Progression follows **Gone Green**'s adoption of the LED but at a slower rate because there is less money available to drive innovation, and the lower cost of electricity will not force as rapid a consumer change.

Halogens maintain their market position in **Consumer Power** due to consumers being less concerned about the cost and their limited awareness, and motivation to adopt low carbon appliances. As in **Gone Green** CFL deployment will not continue. This view of the persistence of halogens was supported by stakeholder feedback received in 2013 and reinforced in 2014 where, of those polled, the majority view was that 20% of light bulbs would be halogen in 2030. Today they represent 39% of light bulbs.

20%

20% of light bulbs would be halogen in 2030

[3] Halogen Banning: EU laws currently ban Class D halogen lamps by 2018.

Figure 36
Power: annual demand for residential light bulbs in Gone Green

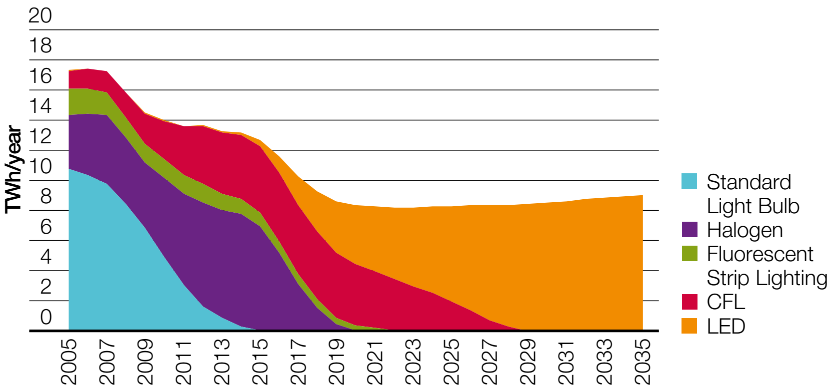
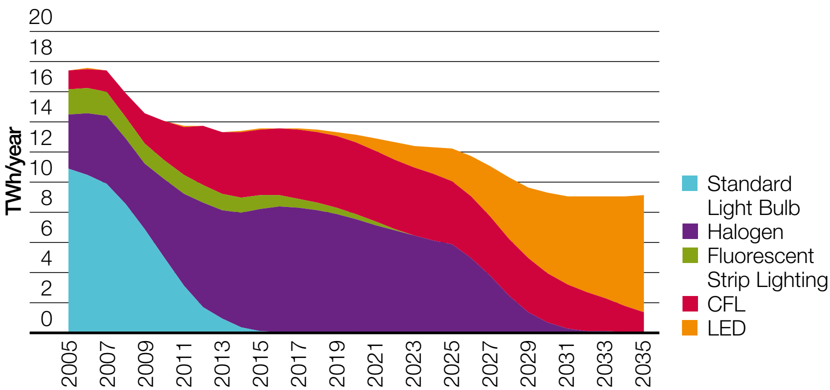


Figure 37
Power: annual demand for residential light bulbs in Slow Progression



Residential demand

Figure 38
Power: annual demand for residential light bulbs in No Progression

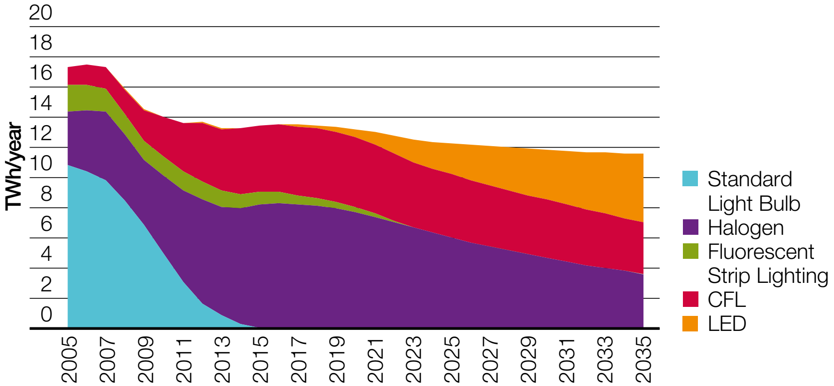
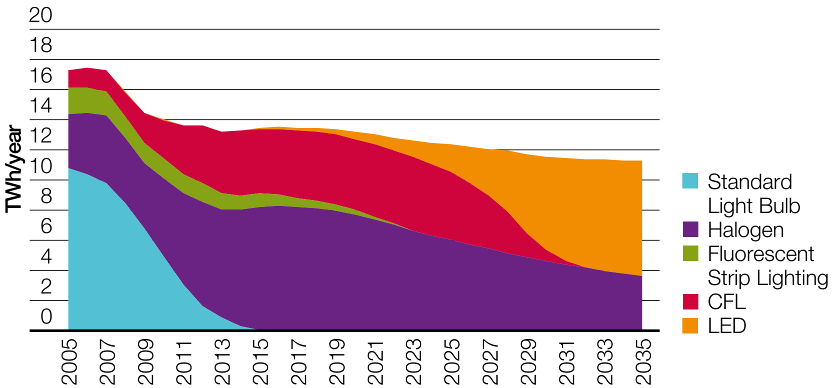


Figure 39
Power: annual demand for residential light bulbs in Consumer Power



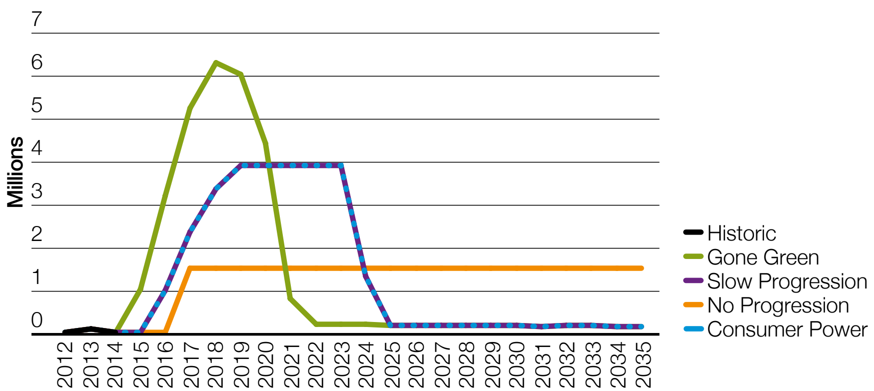
Chapter four

4.4.4
Residential electricity smart meters

We have used three potential rollout programmes for residential electricity smart meters. In **Gone Green** we have adopted DECC's profile which peaks at around 6 million electrical smart meters installations per year. For **No Progression** we have delayed the implementation by two years and used historic replacement rates of 1.5 million units per year. For **Slow Progression** and **Consumer Power** we assume that a mid-course is adopted and so the roll out will be delayed by one year and the installation rate will follow a midway position which is capped at almost 4 million units per year.

For the government's electricity smart meter roll-out programme to progress according to plan, we estimate that at its peak in 2018, there will be approximately 6 million installations per year.

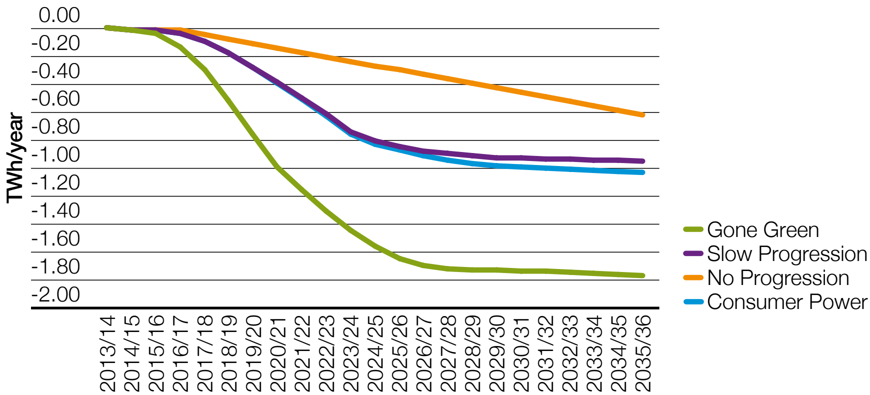
Figure 40
Power: smart meter roll-out profiles



Residential demand

The effect of smart meters on overall demand is better understood following the outcomes of trials. For **Gone Green** there will be the most rapid adoption of smart meters and their functionality as the roll-out programme is delivered fully and consumers are engaged. In **Slow Progression** and **Consumer Power** the installation rate is more muted resulting in slower take up. In **No Progression** there is neither the will to deliver the roll-out or to interact with the meters, nor the prosperity to drive through a rapid deployment of smart meters. Consequently the demand reduction is the lowest.

Figure 41
Power: residential demand reduction through smart meters



4.4.5
Peaks

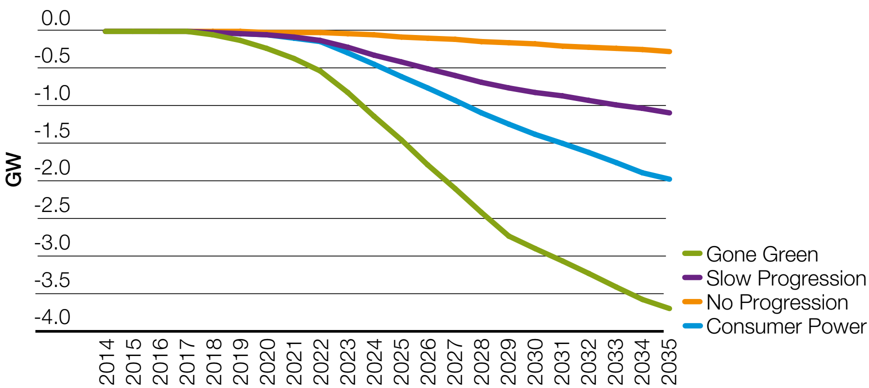
Smart meters allow for within-day banding of retail electricity charges. Such ability will permit associated TOUTs to significantly reduce peak demand by encouraging consumers to use power at other times of the day when the energy prices are lower.

Gone Green shows the biggest reduction in peak demand due to the effects of smart meters. This is driven by an on time smart meter roll-out programme and a rapid and enthusiastic take up of TOUTs.

Slow Progression and **Consumer Power** have a medium take up rate but a slightly delayed implementation rates. **Slow Progression** does not have the affluence to deliver the required changes but does have the ambition, whereas in **Consumer Power** there is the affluence for deployment but not the ambition.

No Progression does not have the affluence or the ambition to deploy and utilise the technology. Consequently it returns the flattest of all the profiles.

Figure 42
Power: peak reduction due to TOUT and smart appliances



Residential demand

Chapter four

Method

Annual demand

We create residential power demand using a bottom-up method. For each component part we use historical data, where available, as our starting point. The main source being DECC's Energy Consumption in the UK[4]. Then we create projections using a selection of historic assessments, household projection data provided by external consultants, outcomes from reported external projects', regression analysis, deterministic and econometric methods. These we benchmark against stakeholder feedback and other external projections and trial results. We adjust each projection with our scenarios' assumptions to create the final results for each component. We combine these to form the residential demand. The components parts we use are:

Appliances

- cold appliances
- wet appliances
- consumer electronics
- home computing
- cooking
- telecommunication and others.

Heating

- resistive heating
- resistive hot water
- air conditioning
- low carbon heating technologies.

Lighting

Time of use tariffs

To model the reduction created by the installation of TOUTs, we took from Customer Led Network Revolution's[5] a figure of 2.8% as the maximum residential annual demand reduction. This figure has then been adjusted downwards in response to other factors such as the roll-out rate of smart meters and engagement level of consumers within the scenarios.

To model the effects of residential TOUTs we have made a number of assumptions such as the time extent of the tariffs and the percentage of people whom are engaged in changing their power consumption pattern. These assumptions are supported by the outcomes of projects, in particular those from Ofgem's Low Carbon Network Fund, Customer-Led Network Revolution and Low Carbon London[6].

However, there still remain a number of uncertainties, which could significantly change how the consumer could or would react to TOUTs, for example:

- profile of the smart meter roll-out
- timing of the introduction of TOUTs
- structure and mechanics of the TOUTs
- differentials in the prices attached to TOUTs periods.

Where we have used trial data we have assumed that the results reflect a **Gone Green** society because the participants were volunteers who were engaged in the projects' aims. We have varied the proportion willing to change dependent on the scenario. As a basis we use data including Ofgem's categorisation of consumer groups by switching behaviour[7] to attempt to identify behavioural types. Feedback from the 2014/15 consultation cycle, showing that the majority of stakeholders thought that 20-40% of consumers would change their behaviour as a result of TOUTs, accorded with our projection range.

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[4] https://www.gov.uk/government/statistics/energy-consumption-in-the-uk

[5] http://www.networkrevolution.co.uk/

[6] http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-%28LCL%29/

[7] https://www.ofgem.gov.uk/ofgem-publications/39708/rmrfinal.pdf

For the smart appliance effect on peak demand we assume that those appliances whose demand could be moved from peak time would do so under the TOUT modelling. We have not included the effect of TOUTs on heat pump usage during the peak periods as we assume it is unlikely that they will be turned off when they are most needed to heat homes on winter evenings.

Heating

Our analysis of residential heat demand includes routes to improving energy efficiency by improving the efficiencies of existing products, through boiler replacements and insulation, and introducing new technologies including heat pumps and fuel cells.

For our 2015 scenarios we commissioned a new modelling tool, which was built with the support of Delta Energy and Environment, to add further depth to our analysis. We have included a larger variety of new technologies (last year only considering ASHP), including hybrid, gas and ground-source heat pumps, micro-CHP units, and fuel cells. The new model considers 22 housing segments, four of which are new build homes. These are broken down by magnitude of thermal demand and property type. The model considers whether the 13 technology types physically fit within each of the 22 residential property segments from the thermal requirement of the property and the size or requirements of the technology. An assessment of the economic drivers and constraints based on residential retail prices (which vary between scenarios, see the Primary Assumptions in Section 3.2 for more detail) is then completed against these thermal demands. These comprise the rational economic decisions which should be made regarding heating technologies. Additionally, the model then incorporates softer factors which affect the take-up of new technologies, including consumer appetite for new technologies, government support, and installer and manufacturer push.

New builds

We have continued to use evidence-based analysis where possible, however, for topics with less data available we have used a stakeholder-focused approach. In response to stakeholder feedback we have adapted the analysis on building regulations to primarily refer to the Zero Carbon Homes target as opposed to the Passivhaus standard.

Insulation

To calculate the impact of insulation, boiler replacement and smart thermostats we use the average saving per house, as published by Ofgem[8]. In reality the savings would differ between homes dependent on their age, size and behavioural patterns.

We created high, medium and low cases for insulation uptake to explore how effective incentive schemes could be in the future. We assumed that rates reflect the trends seen in the approved and notified Energy Companies Obligation (ECO) rates across 2014 as reported by Ofgem[9]. In addition we adjusted the high case to reflect potential increases following supplementary funding incentives. These insulation ranges are used when calculating thermal demand for choosing heating technologies.

District heat

We have recently commissioned a study to inform our scenarios for 2016. We have aligned our district heating scenarios with the combined heat and power (CHP) scenarios and are maintaining our assumption from FES 2014 that CHP is the main source of heat supply. We also assume that the majority of growth is in new builds as opposed to retrofits.

[8] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65694/7387-calculation-eco-targets-final-ia.pdf

[9] https://www.ofgem.gov.uk/environmental-programmes/energy-company-obligation-eco

Industrial and commercial demand

4.5
Industrial demand

Energy demand in the industrial sector is influenced by the rate of economic growth (an indicator of manufacturing output) and energy prices. Declining energy demand in manufacturing is the underlying trend across all scenarios due to the changing mix of sub-sectors and their different energy intensities and this is set to continue.

Key statistics

- **Consumer Power** is the only scenario with gas demand growth over the next 20 years, limited to 3%
- **Gone Green**'s demand for gas declines by 15 TWh/year by 2035
- All industrial scenarios have decreasing power demands.

3%

Consumer Power is the only scenario with gas demand growth over the next 20 years, limited to 3%

Figure 43
Gas: annual industrial demand

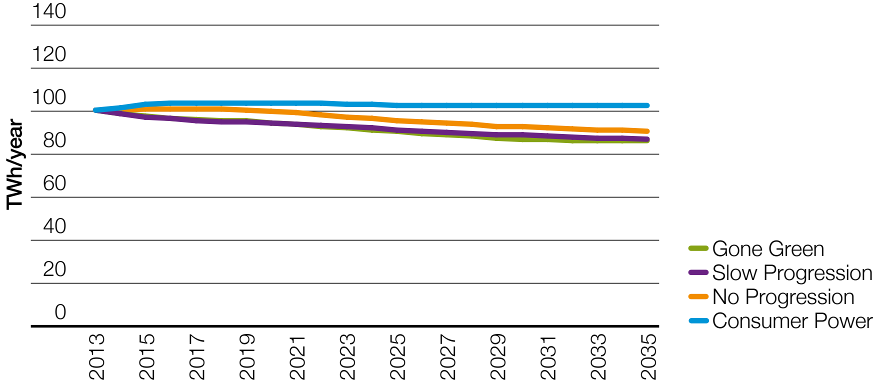
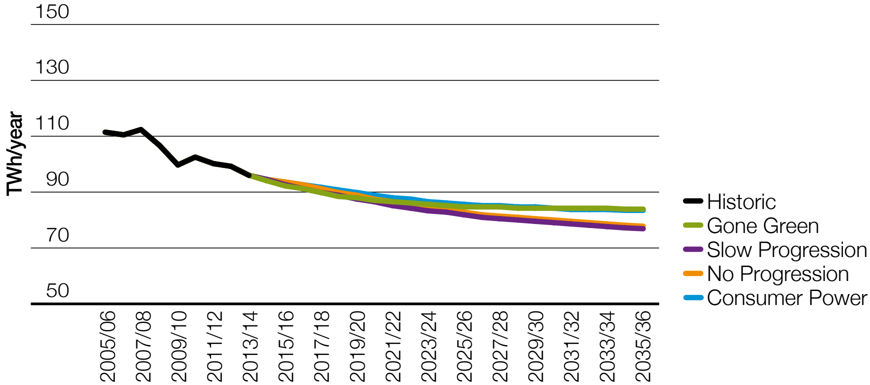


Figure 44
Power: underlying annual industrial demand (excluding losses)



Industrial and commercial demand

4.5.1 Results

Industrial power demand declines in all four scenarios from approximately 90TWh/year today to between 72-79TWh/year in 2035. This is mainly due to the changing mix of industrial sub-sectors and their relative energy intensity, see 4.5.3 for more detail. The stronger economic growth in **Gone Green** and **Consumer Power** helps to delay the underlying trend of declining demand, and is the key reason for the gap between these two scenarios and **No Progression** and **Slow Progression**.

Gone Green has some element of electrification of heat from the adoption of heat pumps. However, with high power prices and expensive up-front costs a strong business case for heat pumps requires the renewable heat incentive (RHI) – which has continued support in **Gone Green**. This support combined with a strong economy leads to 550MW of air source heat pumps (ASHP) being installed by 2035.

Gas demand in the industrial sector has a similar declining outlook in all scenarios apart from **Consumer Power**. The lower gas prices in **Consumer Power** leads to uptake of gas CHP to take advantage of the price spread between power and gas, an additional 1.1GW of installed electrical capacity is installed leading to an increase of 18TWh/year of gas demand.

The CHP effect offsets a more general declining gas demand trend in **No Progression** albeit to a smaller extent than in the more affluent **Consumer Power**, approximately 500MWe of capacity is installed by 2035. The higher gas prices in **Gone Green** and **Slow Progression** lead the declining gas demands; **Gone Green**'s heat pumps further replace gas demand with the additional effect of reducing the total energy requirement.

We have worked with Arup and Oxford Economics to create a new industrial and commercial energy demand model for our 2015 scenarios.

The model looks in detail at the impact on energy demand from changing economic situations, retail prices and new technologies. It does this by breaking down energy demand into 24 economic sub-sectors for more granular interrogation. Gross value added (GVA) per subsector can then be applied in the model and individual trends realised.

Power and gas demand modelling is combined into a single application allowing the relationship between gas and power demands to be further observed due to price differentials; this includes the impact of gas CHP installations to use gas to generate power on-site.

4.5.2
Industrial heat pumps

Heat pumps, in this report, refer to pumps capable of producing low grade heat useful for space heating or hot water demand. These pumps cannot replace gas demand which is used to satisfy high grade process heating demand. **Gone Green** has the drive from government to reduce carbon emissions, partly through electrification of heat. However, this space heating demand is a small part of the total thermal demand across the high intensity sub-sectors of mineral products, refining, chemicals, metals, printing and textiles where heat pumps are currently unsuitable.

4.5.3
Industrial combined heat and power

CHP capacity is already installed in high intensity industry, constraining the possibility for further growth in the sector. Installed capacity ranges from very large pseudo-Power Stations (200MWe installations) in the refining sectors to much smaller factory size CHP (3-4MWe) in manufacturing processes like food and beverages or machinery and equipment. These CHP units are classed as distributed generation, unlike commercial CHP which is classed as micro-generation (<1MWe). [Read more about CHP in the Power Supply section, in chapter 5]

Industrial and commercial demand

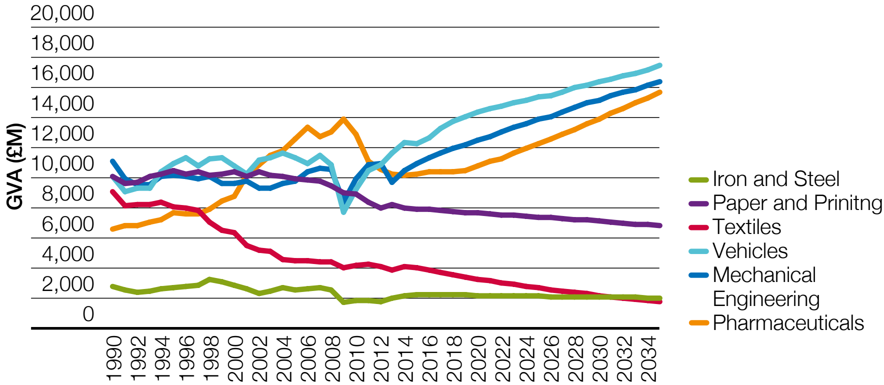
Chapter four

4.5.4
Industrial economic outlook

The underlying price and economic outlook in each scenario is the same across the industrial and commercial sectors. See the commercial section for more detail.

The industrial landscape is changing in the UK and this is one reason why GVA growth in the sector does not lead to proportionally changed energy demands, see Figure 45 which uses Oxford Economics' data. There is strong growth forecast in mechanical engineering GVA but this does not translate into energy consumption. Pharmaceuticals are also set to have strong growth and are the fourth largest contributor to industrial GVA today but have the lowest energy demands. GVA from textiles has halved between 1990 and 2014 and looks set to halve again by 2035, with the subsequent reduction in demand. Paper and printing, the third largest GVA out of 13 industrial sub-sectors in 1990, retreats to seventh largest in 2035.

Figure 45
Selected industrial sub-sector GVA



These shifts to the dominant contributors to UK industrial output change the fundamental industrial energy demand dynamic. Higher intensity sectors are shrinking, reducing energy demands proportionally. This explains the underlying decline to industrial energy demands, despite buoyant GVA, and why economic growth is decoupling from energy demand at a national level.

4.5.5
Industrial and commercial power DSR

Demand side response (DSR) we define as a deliberate change to an end user's natural pattern of metered electricity consumption brought about by a signal from another party.

The Triad charging regime provides one way that large industrial users of electricity can reduce their energy charges by reducing consumption over peak periods. 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. National Grid uses the Triad to determine charges for demand customers with half-hour metering. Their charge for the year is based on a tariff which is multiplied by their average demand during the three Triad half-hours.

There are also emerging industry-led engagement activities such as 'Power Responsive' which seeks a collaborative approach towards realising the DSR potential in both the business and residential sectors. Power Responsive is a framework to facilitate the rapid acceptance of demand side solutions. It will turn debate into action. Its goal is for all businesses to realise cost savings and to secure energy amenity now and in the future[1].

We recognise that the demand side response community is a key stakeholder group for us to fully engage with in our role as System Operator and residual balancer. Currently we are actively seeking the views of existing DSR contracted parties on a range of topics to facilitate the delivery of DSR within our balancing services in order to address current issues, develop and implement opportunities and share knowledge and collaborate.

We conducted a literature review on DSR to search for information on its potential effects. This search involved reviewing both theoretical and trial outcomes which were available in the public domain. It highlighted to us both a scarcity of solid data and, from what was available, a wide range of conclusions. We adopted the less extreme conclusions in order to develop a credible model.

Similar to the residential TOUT section 4.4.5, the strength of the DSR response will be dependent on what the market place offers and where the most value for such offerings can be realised. As yet there is uncertainty as to what form these value streams will take but work to map out the value streams has been instigated.

For all of our scenarios, we assume a 1 GW Triad reduction as the present state (see Methodology section for an explanation of Triad). The projections then reduce in 2016, when a modification to the Balancing and Settlement Code starts to take effect[2]. This requires certain businesses to be settled half-hourly and as such they have the potential to be exposed to the within-day price variations of electricity. This will introduce a driver for businesses to use less power at peak, as power prices should be at their highest.

[1] For more information on Power Responsive please see: http://www.powerresponsive.com/

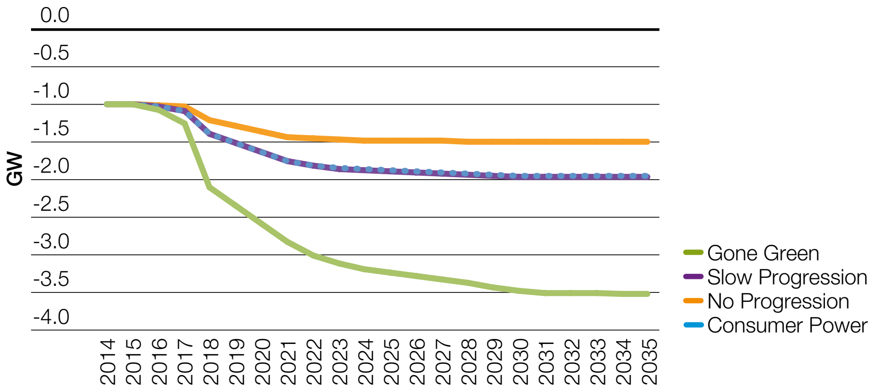
[2] Balancing and Settlement Code (BSC) P272: Mandatory Half Hourly Settlement for Profile Classes 5-8.

Industrial and commercial demand

From winter 2018/19 the DSRs which are contracted under the capacity mechanism will be available and, it is assumed, they will remain in place thereafter. In the same year, we assume that DSR under short term operating reserves (STOR) will be available to the capacity mechanism, where they will be able to access additional revenues. We see this dual availability repositioning taking place over four years and then remaining stable. Thereafter, new markets and revenue streams will open up as a result of this changing environment. This market place will reach maturity by 2030.

For **Gone Green**, we adopted a higher technical uptake rate and a higher utilisation rate of DSR. This is because the price of electricity will be high, there will be greater peak demand and hence there will be relatively larger savings to be made. There will also be an ambition to encourage such behaviour changes. In **No Progression** the cost of power will be lower and so the savings will be much less; consequently, we used more pessimistic figures. For **Slow Progression** and **Consumer Power** we used mid-ranges, see Figure 46.

Figure 46
Power: industrial and commercial demand side response peak power reduction



Method for industrial and commercial demands

Economic data was purchased from Experian and Oxford Economics and used to create a high and low case for UK economic growth. Retail energy prices are benchmarked against DECC's scenarios.

The model examines 24 sub-sectors and their individual energy demands, giving a detailed view of GB demand, and uses an error correcting model to produce projections for each sub-sector individually. The model then has two further modules to investigate the economics of increasing energy efficiency (e.g. heat recovery) and new technologies such as on generation (e.g. CHP) or different heating solutions (e.g. biomass boilers).

These modules consider the economics of installing particular technologies from the capital costs, on-going maintenance costs, fuel costs and incentives. These are used along with macro financial indicators such as gearing ratios and internal rate of return (IRR) for each subsector to consider if the investment is economical and the likely uptake rates of any particular technology or initiative. This allows us to adjust the relative cost-benefits to see what is required to encourage take up of alternate heating solutions and understand the impact of prices on on-site generation which give our scenarios a wider range.

We make use of Experian's economic foresight to set our baseline of UK economic growth. Our stakeholders told us that they did not expect to see higher growth than this and so we flexed the growth of GDP down to set our low growth scenario using Oxford Economics' model.

Gone Green has high power and gas prices; the cost of new renewable generation is high and this is passed on to the customer. The high retail gas prices relate to the ambition of decarbonisation: we have assumed there will be some intervention on the gas prices to discourage the use of gas. Economic growth is higher at an average of 2.4% pa.

Slow Progression uses our baseline power prices and high gas prices. The scenario is following **Gone Green**'s footsteps but at a slower rate – there are less renewables on the system so the price is kept lower. However the ambition for decarbonisation remains the same resulting in the higher gas prices. Economic growth is lower at an average of 1.9% pa.

No Progression has low power prices – it has the least investment into renewable generation – and baseline gas prices. Gas demand continues to be prevalent for heating and generation. Economic growth is lower at an average of 1.9% pa.

Consumer Power has low gas prices and baseline power prices due to the levels of renewables. Its lower gas prices stems from UK domestic supply making up a larger proportion of gas supplies and the inertia to going green, allowing gas to be utilised despite the carbon implications. Economic growth is higher at an average of 2.4% pa.

Industrial and commercial demand

DSR

We see there being a number of enablers to DSR including:

- Balancing services
  - – Demand Side Balancing Reserve
  - – Short Term Operating Reserve
  - – Firm Frequency Response
  - – Frequency Control Demand Management
- Electricity Market Reform mechanism
- Triad avoidance actions
- Turn Down contracts with suppliers
- TOUTs
- Interruption Contracts with distribution network operators.

As Triad avoidance operates on a business by business basis, there is no definitive network system data on the magnitude of the effect. Consequently an estimate is produced by National Grid and this has been used as a starting point in our modelling.

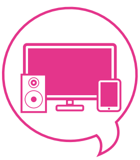
Data from the Capacity Mechanism auction and from National Grid's balancing services are used to further inform our modelling of DSR.

4.6
Commercial demand

Commercial gas and power demand has a weak relationship with economic growth. Productivity doesn't necessarily require the production of more objects but instead can come from scaling efficiency gains such as the use of information technology. Demand is influenced more heavily by energy prices. This sector is providing most of the nation's growth, allowing more investment into technologies like CHP to produce lower cost electricity, and heat pumps to produce renewable heating.

Key statistics

- Underlying annual power demand is relatively flat across all of our scenarios. Variations in demand range from a reduction of 10 TWh/year in **Gone Green** in 2035 to an increase of 5 TWh/year by the same time in **Consumer Power**
- This range is reversed for gas demand: **Gone Green** loses nearly 40 TWh/year and **Consumer Power** increases by about 20 TWh/year by 2035
- Heat pumps add 1.5 TWh/year to power demand in **Gone Green** by 2020
- New CHP accounts for 7.9 TWh/year of additional gas demand between now and 2020 in **Consumer Power**.



20 TWh

Gone Green loses nearly 40 TWh/year and **Consumer Power** increases by about 20 TWh/year by 2035

Industrial and commercial demand

Figure 47
Gas: annual commercial demand

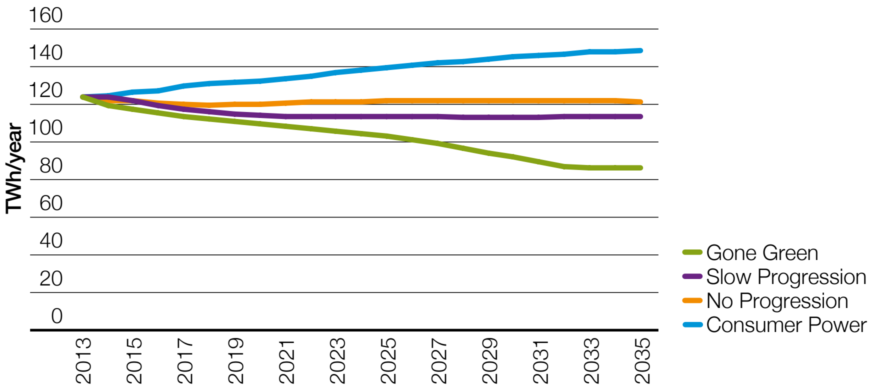
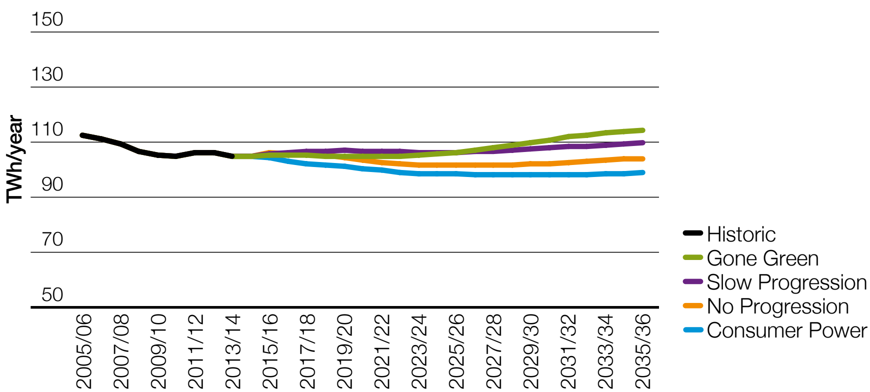


Figure 48
Power: annual commercial demand (excluding losses)



4.6.1 Results

Consumer Power has a relatively stable gas price with escalating electricity prices. Under such conditions the buildings that use electricity for heating start to switch to gas boilers. As such approximately 7 TWh/year of power demand switches by 2035, close to 40% of space heating, hot water and catering related demands. Furthermore, commercial buildings also install gas CHP to avoid buying power from the grid and benefit from lower cost electricity supplies which causes strong growth in gas demands. However, the underlying power demand is not reducing in this scenario.

Gone Green shows the opposite situation occurring, heat is further electrified to reduce its carbon intensity and the switch is instead from gas boilers to electrical heat pumps.

Heat pumps are the low carbon heating solution of choice, with biomass also used in CHP systems. Both are economically attractive due to subsidies, higher gas prices, continued R&D, and increased production bringing economies of scale and capital cost savings. Buildings with waste heat (e.g. refrigeration) can utilise the waste as a resource to make heat pumps more efficient, bringing larger cost savings and a better business case.

Both **Slow Progression** and **No Progression** have fairly stable energy demands; gas is favoured in **No Progression** and power in **Slow Progression** reflecting the higher green ambition in the **Slow Progression** world. This also reflects the relative increase of power and gas prices compared to each other.

Industrial and commercial demand

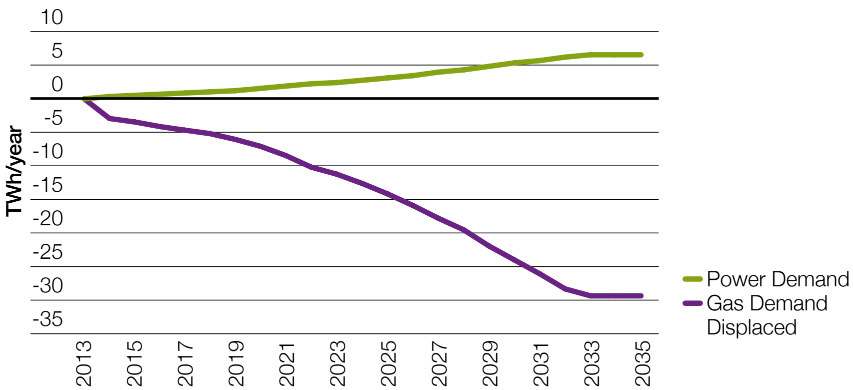
4.6.2
Heat pumps

For electrification and renewable heating to manifest within **Gone Green**, progress has to be made in reducing the capital costs of installing heat pumps along with maintaining incentives to ensure the appliances are economical compared with alternatives. The RHI is funded through the Treasury and is committed until March 2016. In order for **Gone Green** to achieve the 2020 targets the RHI or an alternative mechanism needs to continue to support renewable or low carbon heating from April 2016 onwards.

Additional improvements to the coefficient of performance (COP) from either improved technology or more sophisticated installation setups, such as utilising waste heat from refrigeration, will help too. The combined effect of these leads to a viable business case in **Gone Green** to install heat pumps in commercial buildings.

A high COP, the ratio between electrical input and thermal output, means that the amount of gas offset by installation of heat pumps is several times the increase in new power demand. This ensures that running costs can be similar or lower to alternative gas appliances. In **Gone Green** the average COP is 3.5–4.0 for commercially installed ASHP over the next 20 years. By 2035 2.1 GW of heat pumps are installed, requiring 6.5 TWh/year of power demand but offsetting nearly 30 TWh/year of gas demand.

Figure 49
Change in power and gas demands due to installed commercial heat pumps in Gone Green



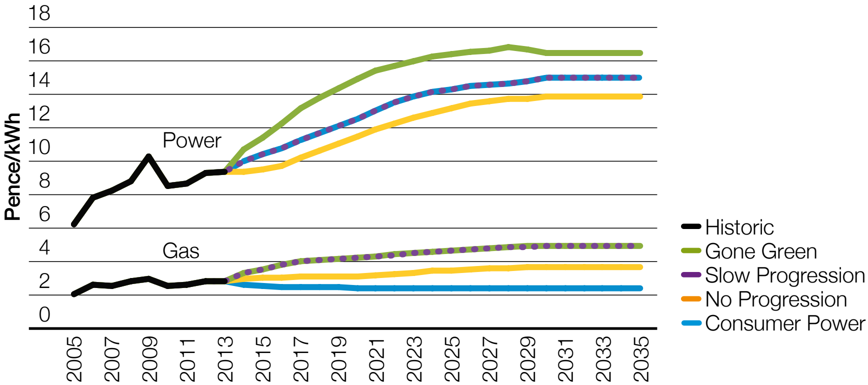
4.6.3
Combined heat and power

CHP uses input energy to produce both electrical energy and thermal energy and is therefore more efficient than producing those two outputs separately. Commercial CHP are generally installed as small scale units with a capacity of <1MW of electrical output and therefore are classed as micro-generation in this report. CHP can have higher overall energy efficiencies compared to conventional gas heating with separate power generation, assuming the heat is used locally and not wasted. Economically, gas CHP could provide lower cost power supplies should retail power and gas prices diverge with electricity becoming relatively more expensive.
The type of input fuel e.g. gas or biomass, has a significant impact on the carbon benefits of on-site CHP.

Should the generation mix progress towards lower carbon sources i.e. carbon intensity progressing to 50gCO_2/kWh by 2030, then the carbon intensity of fossil fuel CHP would result in higher levels than retaining power supplies from the grid and conventional gas heating.

Consumer Power has the highest installation of gas CHP due to the favourable conditions in the scenario. Lower gas prices with base electricity prices and a growing economy, therefore more money to invest, causes the economics for installing gas CHP to be attractive. The other three scenarios share a similar low level of gas CHP installations.

Figure 50
Power and gas retail prices

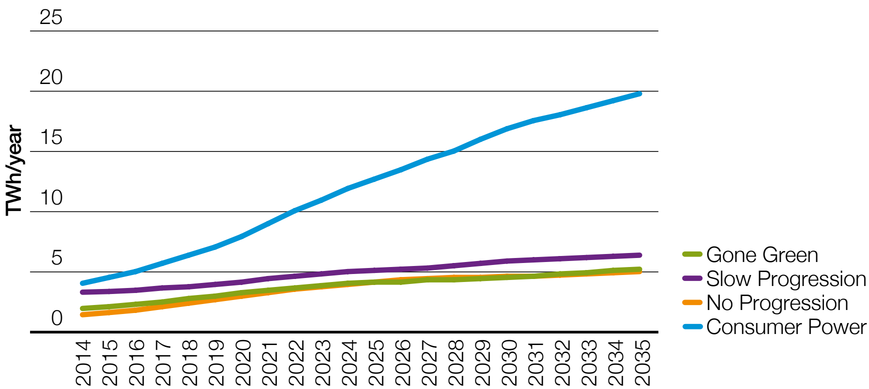


Chapter four

Industrial and commercial demand

Gone Green has the highest uptake of biomass CHP of any of our scenarios. This renewable energy source aligns with the objective of removing carbon emissions from commercial sites. Within this scenario's power generation mix, there is plenty of renewable generation. This results in power from the grid being cleaner and therefore it is greener than the alternative gas CHP.

Figure 51
Gas: demand from additional CHP installation in the commercial sector



Transport

4.7 Transport

From domestic cars to commercial vehicles, including vans and heavy goods vehicles (HGVs), transport is an important area of focus if the UK is going to hit its carbon targets. Electricity and natural gas can both be solutions, giving lower emissions from vehicles in GB. In Gone Green and Consumer Power, electric vehicles (EVs) continue their strong market growth. Natural gas vehicles (NGVs) also make a breakthrough due to good fuel economics and lower emissions.

Key statistics

- Currently NGVs are estimated to be less than 0.1% of the fleet, this is set to grow to 1–3% by 2020 in our scenarios
- Plug-in EVs account for 20,000 cars on Britain's roads but could surpass the one million mark as early as 2022, adding about 2TWh/year to electricity demand
- In 2035, electric vehicles account for an additional 14TWh/year in **Gone Green** and **Consumer Power**, however the additional peak demand in **Gone Green** is 1GW vs 3GW in **Consumer Power**
- In our scenarios, gas demand for vehicles increases to between 5 and 25TWh/year in 2035.

20,000

Plug-in EVs account for 20,000 cars on Britain's roads but could surpass the one million mark as early as 2022, adding about 2TWh/year to electricity demand

Transport

Figure 52
Power: annual demand from electric vehicles (excluding losses)

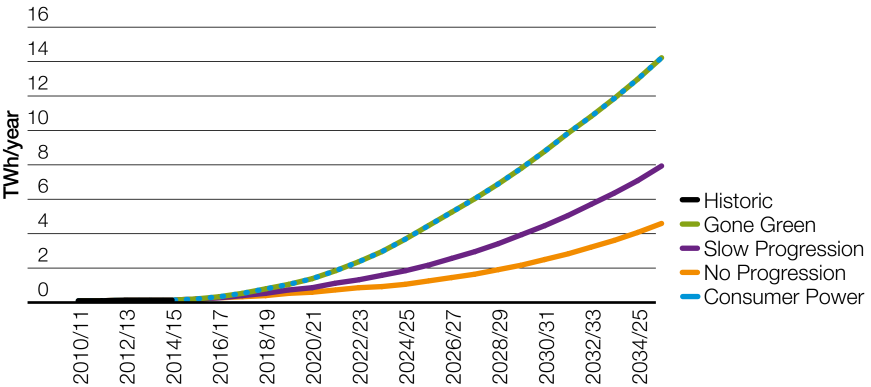
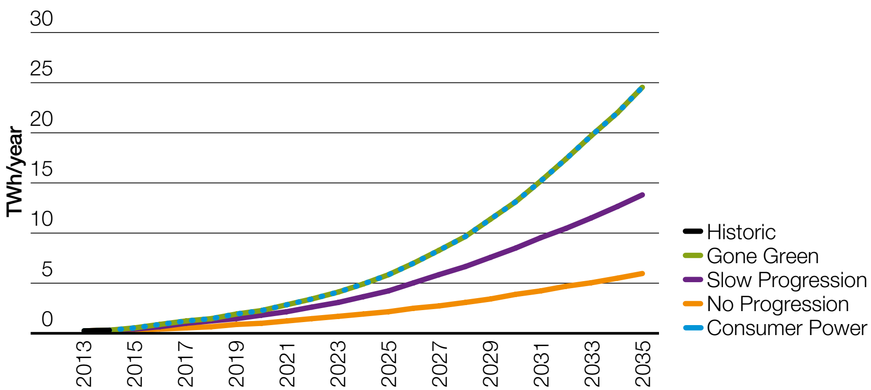


Figure 53
Gas: annual demand from natural gas vehicles



4.7.1
Results – electric vehicles

In this report we have only considered plug-in electric vehicles, which covers pure electric (PEV) and plug-in hybrids (PHEV). EVs which are hybrids with no plug-in recharging mechanism do not have an impact on power demand.

Consumer Power has continued strong growth in the EV market and, with **Gone Green**, the highest uptake of the vehicles. Consumers find the innovative technology and low running costs of electricity compared to petrol appealing and investment in the industry brings down the capital outlay. **Gone Green** has similar results but with environmental concerns given heavier weighting. This is supported by government ambition to decarbonise transport and customers wanting to switch away from internal combustion engines. Recharging stations are easily available allowing for EVs to be used for longer distance travel.

For sales of EVs to continue to grow, battery costs (the most expensive component of an EV) need to come down alongside continued proliferation of fast charging points to combat "range anxiety".

For **No Progression**, the upfront cost implications prevent customers from buying into EVs, cost reductions (mainly batteries) aren't realised and conventional vehicles continue to dominate sales.

This is also true to some extent in **Slow Progression**. However, consumers have the desire to decarbonise their transport with the wish to balance it against the cost and convenience. This leads to demand for PHEV which maximise fuel efficiencies from internal combustion engines without compromising on range and without the cost of large expensive batteries. The same number of PEV is added to GB's roads as in **No Progression**.

The government has committed to support purchases of new EVs with a 35% discount (up to £5,000) for a car and 20% discount for a light goods vehicle (up to £8,000). Funding is available for on-street charging points and support for EVs has led to the Highways Agency installing quick charge points at most motorway service stations to combat the drawback of limited range. These factors have helped to make EVs competitive against conventional vehicles thus contributing to the high growth in sales over the last two years.

Transport

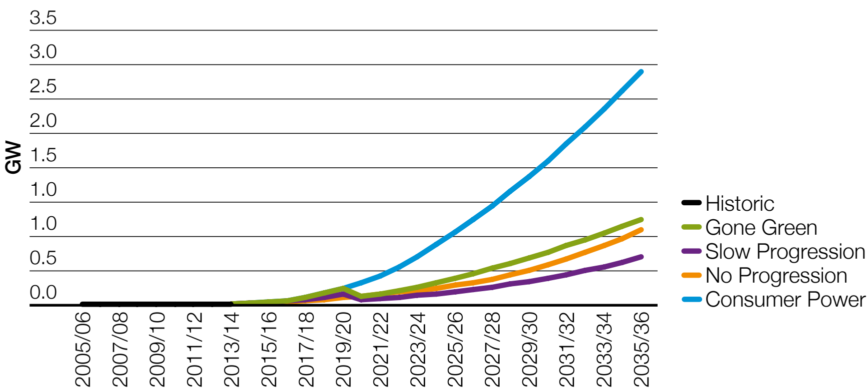
4.7.2
EV peak demand

We apply one of two profile options to our four different scenarios. The first profile is based upon an uninhibited charging regime that operates in all our scenarios up to 2020 and thereafter only in **No Progression** and **Consumer Power**. Secondly, for **Gone Green** and **Slow Progression**, we assume that TOUTs will come into effect in 2020, in line with the domestic roll-out programme and for the same reasons (see the Methodology for section 4.4). This explains why there is a dip in these two profiles and then a rise in their trajectories.

The implementation of TOUTs separates the **Gone Green** and **Consumer Power** profiles shown in Figure 54. It also raises peak demand for **No Progression** above that for **Slow Progression**, a reversal of their relative positions in the annual demands.

Peak power demand, in 2035, for **Gone Green** is 71 GW and **Consumer Power** 65 GW and so electric vehicles will only contribute 1.4% and 4.6% respectively to the peak load.

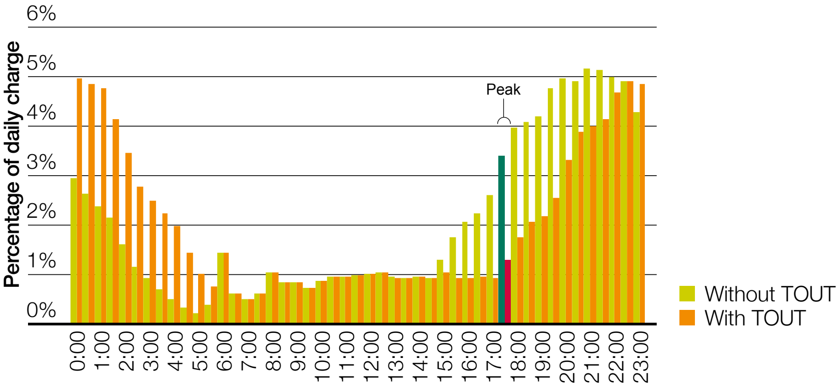
Figure 54
Power: peak demand contribution from electric vehicles (excluding losses)



The uninhibited profile, based on findings from the Consumer-led Network Revolution trials[1], assumes that consumer will charge their vehicles when it is convenient to them and that is when they arrive home, or work finishes, adding a significant load during the peak period.

The constrained profile applies a TOUT element in the early evening period, in order to encourage displacement of demand by two hours. Consequently the constrained demand at 17:30hrs is reduced to 38% of the uninhibited value.

Figure 55
Electric vehicle charging profile for a January day



[1] http://www.networkrevolution.co.uk/project-library/insight-report-electric-vehicles/

Transport

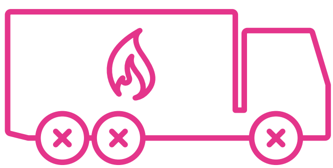
4.7.3
Natural gas vehicles

NGV are defined as vehicles that use natural gas, predominantly methane, as part of their drive chain. This could be a hybrid system running with diesel, or running only from gas. Gas is stored for use in the vehicle in two types: liquefied or compressed natural gas. Liquefied natural gas (LNG) is either taken by tanker to the pump or liquefied on-site while compressed nature gas (CNG) is gas stored at a high pressure, around 200 bar, compressed at the fuelling station. Typically CNG vehicles are attractive for back to depot applications (logistics, public transport fleets) where they can be regularly refuelled at a purpose built location. LNG is more attractive for long haulage vehicles due to the higher energy density which leads to additional range.

Advantages of NGVs include:
- lower price of natural gas vs diesel
- quieter engines, allowing for earlier deliveries in residential areas
- lower emissions for CO_2, NOx and particles i.e. enhanced air quality benefits

Disadvantages include:
- shorter ranges
- lack of fuelling infrastructure.

The biggest take up of NGVs occurs in **Gone Green** and **Consumer Power**. The need for decarbonisation in **Gone Green** drives the conversion of the fleets, while in **Consumer Power** motives are driven by the economics of changing fleets to NGVs to take advantage of the lower gas prices. **Slow Progression** has a slower rate of take up due to lower availability of investment capital but with the same market drivers as **Gone Green** for decarbonisation. **No Progression** has the lowest take up, with less intervention and less capital available for investment, the infrastructure isn't built, preventing NGVs being viable options other than within private refuelling infrastructure.



4.7.4
Rail demand

Our stakeholder engagement suggests that there will be continued growth in the demand from trains but there are two potential trajectories. In **Gone Green** and **Slow Progression** a growth rate greater than the historical average is predicted; that is 2.5% year on year. This increases today's demand of 4.1 TWh/year to 2035's value of 7.1 TWh/year. This increase is driven by policy decisions to invest more in the electrification of the network. In **No Progression** and **Consumer Power** we have adopted the historical average of 1.5% percent which in 2035 gives a demand of 5.7 TWh/year.

Transport

Method

Our transport analysis is built on feedback from our stakeholder engagement. Using historic figures from The Society of Motor Manufacturers and Traders (SMMT) and Driver and Vehicle Licensing Agency (DVLA) we have applied growth rates for pure electric and plug-in hybrids. This has given us total numbers of vehicles in each year. Then data on the average number of miles driven per year and kWh/mile from the current tranche of EVs is applied to calculate the energy demands for those vehicles. We asked our stakeholders what level they thought EV sales would reach in 2030 and used their feedback to calibrate the growth rates. The feedback was that our growth rates from the FES 2014 analysis were in line with expectations and the 2014 actual numbers were in our scenario's envelope so there is only a small change in the numbers from year to year.

Last year we had assumed that London would be a very high growth area for EVs. This has now changed to reflect the data that London is a lower growth area for EVs at this time and therefore we have lowered the proportion of EVs in London. With shorter distances of travel in London this meant that we had calculated slightly lower power demands.

For the within-day charging profiles we use data from the Customer-Led Network Revolution trials[2] to inform us of the likely within-day charge profile for a system peak day.

We have added NGVs to our analysis this year and have followed a similar approach to our EV analysis. We asked stakeholders at what level they thought NGVs would be in the GB fleet in 2030 and used this to calibrate growth rates. With total numbers of vehicles we then considered drivetrains (LNG, CNG and hybrid) and their suitability to different size, and modes of vehicles. This, along with data on diesel consumptions for vehicles, is used to calculate gas demands to effectively offset diesel demands.

There is very little data on NGVs at this time as the market is at an early stage. We will look to see what new data will be collected in the future that can influence our methodology.

For railways we have used National Rail's published business plans and energy consumption in the UK's Transport data tables[3] as our start point.

[2] http://www.networkrevolution.co.uk/wp-content/uploads/2014/08/CLNRL077-TC6.zip

[3] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/338678/transport.xls

Chapter five

Power supply

Interconnectors

Gas supply

Power supply

5.1
Power supply

Our power supply scenarios consider the sources of generation that will be used to meet power demand now and into the future.

The Capacity Market (CM) auction results and the Contracts for Difference (CfD) awards have provided some certainty around the sources of power supply in the medium term. However the long-term evolution of the power supply background remains uncertain given the ever changing political, environmental, social and technological landscape.

Our **Gone Green** scenario meets the climate change targets facilitated by a strong green agenda and underlying growth in the economy. In **Slow Progression**, the transition to low carbon and renewable technologies is delayed by financial constraints, resulting in a slower deployment of these technologies compared to **Gone Green**. In **Consumer Power**, significant volumes of generation connect at local level facilitating emerging technologies to make their mark on the power supply landscape. Our **No Progression** scenario is dominated by established and comparatively cheaper forms of generation given the financial constraints and lack of focus on decarbonisation of the economy.

Key statistics

- In **Gone Green** renewable technologies generate 34% of power supplied, facilitating the government's ambitions of sourcing 15% of energy from renewable technologies by 2020.
- In **Consumer Power** small scale generation represents 40% of installed generation capacity by 2035/36.
- Thermal generation remains the backbone of the supply portfolio, providing flexibility to the market and electricity network requirements.

The power supply scenarios provide four alternative outlooks of how the power supply landscape may evolve in the future. The scenarios consider how political ambition, environmental legislation, the economic climate, technological advancements and social engagement influence electricity generation. Our scenarios consider all sources of generation irrespective of where and how they are connected. They show the total Great Britain (GB) power supply capacity connected to the national (transmission) and local (distribution) networks together with generation installed on domestic dwellings and industrial and commercial buildings (micro generation).

5.1.1
Rules and assumptions

Our scenarios have been developed to be consistent with the rules and assumptions applicable to power supply, please refer to chapter 3.

Security of supply reliability standard

All four of our scenarios have been developed to meet the security of supply reliability standard from 2018/19 onwards, when the CM becomes operational. The reliability standard has been set by the Department of Energy and Climate Change (DECC) at 3 hours per year based on the loss of load expectation (LOLE) metric[1,2], please refer to Chapter 7 – Security of Supply case study for more information.

Levy control framework

Our scenarios also consider the amount of financial support available for low carbon and renewable generation. The amount spent on low carbon and renewable generation, as depicted by each of our scenarios out to 2020/21, must stay within the budget as specified by the Levy Control Framework (LCF)[3].

Levy control framework

DECC and HM Treasury have established the LCF which places a financial cap on levy-funded spending.

An upper limit of £7.6 billion (2011/12 prices) was set for 2020/21 on the combined cost of levy-funded electricity policies within the LCF: Renewables Obligation (RO), Feed-in Tariff (FiT) and CfD including the Final Investment Decision Enabling for Renewable (FIDER).

Levy Control Framework – upper expenditure profile

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21
£m	3,300	4,300	4,900	5,600	6,450	7,000	7,600

Although the cumulative spend is within the LCF budget, there are three separate occasions where our scenarios (**Gone Green** and **Consumer Power**) exceed the year on year spending currently allocated by the government: 2016/17 in **Consumer Power**, and 2019/20 and 2020/21 in **Consumer Power** and **Gone Green**.

[1] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/238867/Consultation_on_the_draft_Delivery_Plan__amended_.pdf - Chapter 3

[2] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/223653/emr_consultation_annex_c.pdf

[3] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/223654/emr_consultation_annex_d.pdf

Power supply

For 2019/20 and 2020/21, this can be attributed to the profile of the budget not accounting for the recent slippages in projects timeline. This has resulted in projects commissioning later than anticipated which is not accounted for within the annual budget allocation.

The overspend in **Consumer Power** in 2016/17 is due to an increase in the level of potential projects connecting to the electricity network by March 2017 as developers seek to acquire RO qualification before the scheme closes.

Our analysis indicates that a review of how the LCF allocates the money, between the different schemes (as described in the support mechanism overview below), in each year may be required. Given recent deployment rates, a review will ensure that the available money has been apportioned appropriately within the framework, whilst kept within the overall budget.

Low carbon technologies support mechanism overview

FiT is a payment that a renewable or low-carbon generator receives for each MWh of electricity generated. FiTs apply to small scale generation projects (<5MW) and set a payment level based on the technology and the size of the plant. This payment is a premium added to the wholesale electricity price. An optional export tariff is available for electricity exported to the grid.

Renewable Obligation Certificates (ROC) are certificates issued to eligible generators for the renewable electricity they produce. For each MWh of electricity generated, a generator receives a number of ROCs depending on the technology and the project size. Similar to the FiT scheme, ROCs are a premium added to the wholesale electricity price. The RO scheme was closed in March 2015 for solar photovoltaic (PV) and is set to close in March 2017 for all other eligible technologies[4].

CfD is a private law contract between a low carbon electricity generator and the Low Carbon Contracts Company (LCCC). It requires generators to sell energy to the market. To reduce exposure to fluctuating electricity prices a variable top-up from the market price to a pre-agreed 'strike price' is provided. At times when the market price exceeds the strike price, the generator is required to pay back the difference.

[4] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/367365/statutory_security_of_supply_report.pdf – Pages 19 and 20

5.1.2
Changing energy landscape

Our 2015 scenarios have been shaped by important political, economic and technological developments which took place during 2014/15 in addition to comments received from our stakeholders.

2018/19 Capacity Market auction results
The 2018/19 CM[5] auction, as described in the support mechanism overview below, has provided some clarity regarding the future generation mix, with the results favouring existing over new and small over large generation.

The results of the 2018/19 CM are included in all of our 2015 power supply scenarios, for the minimum duration of the awarded contract[6].

Capacity Market overview

CM contracts are awarded for the provision of capacity to the electricity system. These contracts ensure that at times of peak demand there is enough available capacity to meet the security of supply standard determined by the Secretary of State. Eligible providers are new and existing thermal power stations and pump-storage plants, existing nuclear and hydro power stations, DSR providers and interconnectors (from 2019/20). The allocation of CM contracts and payment level for each MW of capacity is determined through a competitive auction among the eligible providers. The clearing price for the 2018/19 auction was £19.40/kW/year.

Contracts for Difference
CfD allocation round one results provided clarity on the deployment of renewable generation over the next few years although additional renewable generation will be required to achieve the 2020 climate change targets. The awards allocated through round one are included in all of our 2015 power supply scenarios[7].

Thermal generation – challenging economic conditions
The current challenging economic conditions for thermal generation have resulted in earlier than anticipated plant closures, power stations mothballing or reducing their capacity (~2 GW reduction in transmission connected capacity, for 2015/16, when compared to FES 2014). The electricity market is not providing the necessary signals required for large scale investment. As a result, all of our scenario have only one large scale Combined Cycle Gas Turbine (CCGT) power station under construction.

[5] https://www.gov.uk/government/collections/electricity-market-reform-capacity-market
[6] https://www.gov.uk/government/statistics/capacity-market-location-of-provisional-results
[7] https://www.gov.uk/government/statistics/contracts-for-difference-cfd-allocation-round-one-outcome

Power supply

Environmental legislation

Environmental legislation will continue to shape the construction of new thermal plant and the operational lifespan of existing fossil fuel power stations. The introduction of the Industrial Emissions Directive (IED)[8] will impact coal-fired generation and a considerable portion of the existing gas-fired power stations. The new environmental standard may result in further capacity reduction by the end of this decade, as power stations owners decide to opt-out from the IED requirements.

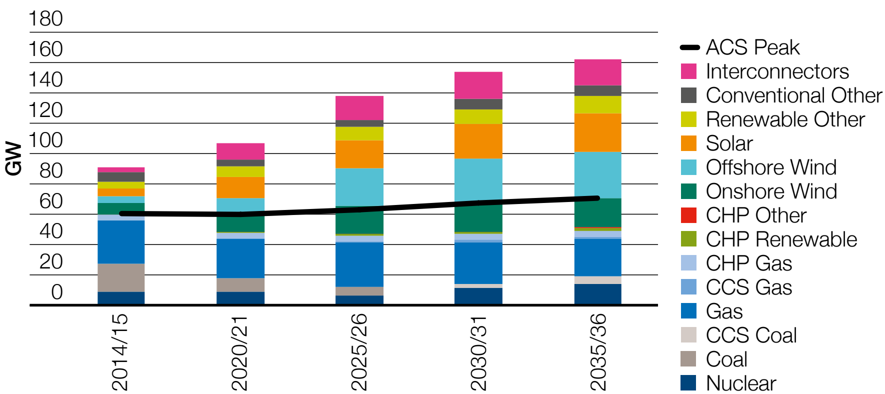
5.1.2.5. Interconnectors

Compared to FES 2014, there has been an increase in interconnector capacity. GB remains a net importer of electricity with only our **Gone Green** scenario showing net exports by mid 2030s. The contribution to security of supply from interconnectors increases while flows at winter peak remain dependent on variable generation and relative prices between GB and Europe. For further information on our 2015 interconnector assumptions, please refer to chapter 5.2.

5.1.3 Gone Green

Our **Gone Green** scenario meets the climate targets facilitated by a strong green agenda and underlying growth in the economy. The achievement of the climate change targets requires the deployment of significant volumes of renewable generation, changing the energy landscape to one shaped by low carbon and renewable technologies, as illustrated in Figures 56 and 57. Table 1 shows the installed capacity and output levels for our **Gone Green** scenario.

Figure 56
***Gone Green:** installed capacity*



[8] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/367365/statutory_security_of_supply_report.pdf – Pages 19 and 20

Figure 57
***Gone Green:** power output*

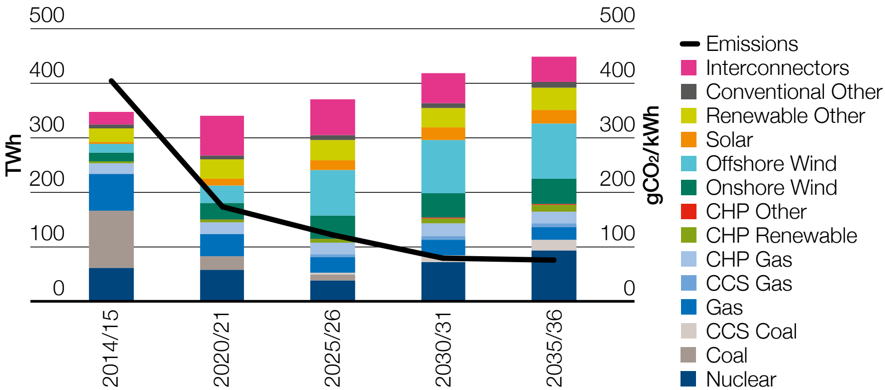


Table 1
***Gone Green** installed capacity and electricity outputs*

Technology	2020/21		2030/31	
	Capacity(GW)	**Output (TWh)**	**Capacity (GW)**	**Output (TWh)**
Nuclear	9.0	57.7	11.3	72.7
Coal	8.7	25.5	0.0	0.0
Gas	26.1	40.3	27.6	28.8
CCS	0.0	0.0	3.9	18.8
CHP	4.7	26.0	5.6	32.6
Onshore Wind	12.7	30.1	18.7	44.4
Offshore Wind	9.5	31.4	29.3	97.4
Solar	13.8	13.3	23.3	22.5
Renewable Other	7.0	35.7	9.4	35.4
Conventional Other	4.4	6.7	6.8	9.9
Interconnectors	10.8	72.1	17.7	54.4

Focus on 2020

Our **Gone Green** scenario illustrates the levels of renewable generation required to meet the 2020 climate change targets. Given the maturity of the technology and the opportunity for large scale and rapid deployment, the growth in renewable generation is centred on wind (onshore and offshore) and solar PV.

The deployment of wind and solar PV out to 2020 results in the installation rates and energy output doubling by the end of this decade.

Power supply

Flexible generation

Our **Gone Green** scenario is heavily influenced by the establishment of low carbon technologies and greater integration with Europe (refer to chapter 5.2). The traditional forms of generation (coal, gas and pumped storage) will continue to play a key role in ensuring security of supply (refer to chapter 7 – Security of Supply case study) and providing flexibility to the GB electricity market and system. Power stations will be required to adapt to the ever changing generation landscape whilst providing the backbone around which the system is operated.

By 2035/36 the gas-fired contribution to annual GB electricity supplies reduces by 43% from today's levels as low carbon generation and increased European integration shape where we source our electricity from.

Environmental legislation

Compliance with the Large Combustion Plant Directive (LCPD)[9] and the forthcoming IED legislation results in reduced capacity from the existing coal, gas and oil power stations as owners decide how they will operate under the tighter emissions regulation. The closure of fossil fuelled power stations requires additional generation to connect in order to maintain security of supply. **Gone Green** shows a substantial volume of CCGT power stations connecting to the system (~9GW) over the next decade before the next generation of nuclear and other low carbon technologies become operational.

Decarbonisation agenda

The decarbonisation agenda is shaped by the successful construction and commissioning of the next generation of nuclear power stations and the commercial scalability of emerging technologies like carbon capture and storage (CCS) and marine over the next 20 years.

Nuclear

The commissioning of the first new nuclear power station, during the first part of the 2020s, is a cornerstone of the **Gone Green** generation mix as the country continues on its pathway to achieve the 2050 environmental targets. Our **Gone Green** scenario has the highest level of installed capacity (~14GW) and output (~20% of the electricity produced) from the nuclear fleet by 2035/36, reinforced by a robust new build programme which also offsets the decommissioning of the majority of the existing nuclear power stations.

The first new nuclear power station, since the 1990s, will be operational by the mid-2020s.

Carbon capture and storage

The commercial breakthrough of CCS within GB will be shaped by the success of the two proposed demonstration projects which are anticipated to be commissioned within the next decade.[10]

Our FES 2015 CCS projections are based on stakeholder feedback received from our FES 2014 consultation. Stakeholders highlighted the uncertainty regarding the commercial scalability of the technology and the limited amount of potential projects. However they also acknowledged the important role it may have in the future as GB strives to achieve its long-term ambition regarding a low carbon economy. We also received queries regarding how plausible it was to have significant amounts of nuclear and CCS included in the same scenario, as predicted in our FES 2014 **Low Carbon Life** scenario.

Our 2015 FES projections for CCS incorporate the comments received from our stakeholders in terms of commercial scalability uncertainty whilst acknowledging the importance of the technology in achieving the long-term decarbonisation agenda.

[9] http://www.whiteroseccs.co.uk/ http://www.shell.co.uk/energy-and-innovation/the-energy-future/peterhead-ccs-project.html

[10] http://www.whiteroseccs.co.uk/ http://www.shell.co.uk/energy-and-innovation/the-energy-future/peterhead-ccs-project.html

> Our 2015 **Gone Green** scenario has ~6 GW of CCS operational by 2035/36 compared to ~11 GW in FES 2014 **Gone Green**.

Marine

Our **Gone Green** scenario recognises the potential which GB has of harnessing the power of the sea and converting it into renewable energy due to the focus on the decarbonisation agenda. The scenario also acknowledges the uncertainty of how specific projects may develop in the future. The proposed tidal lagoons projects located in Wales along with the marine projects up in the Pentland Firth, Orkney are at the forefront of establishing marine technology within the GB generation mix. By 2035/36, the installed capacity for marine technology reaches ~5 GW based on the new tidal lagoon projects proposals and recent grid connection terminations for the Orkney projects.

2020s

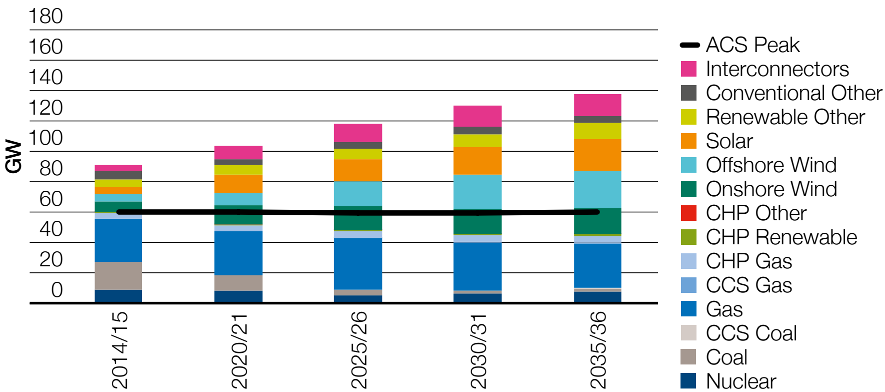
The first new nuclear power station, since the 1990s, will be operational by the mid-2020s.

Power supply

5.1.4
Slow Progression

Our **Slow Progression** scenario is shaped by the transition to low carbon and renewable technologies. The constraints on finance result in a slower deployment of these technologies compared to **Gone Green** as illustrated in Figures 58 and 59 and Table 2.

Figure 58
***Slow Progression:** installed capacity*



Chapter five

Figure 59
***Slow Progression:** power output*

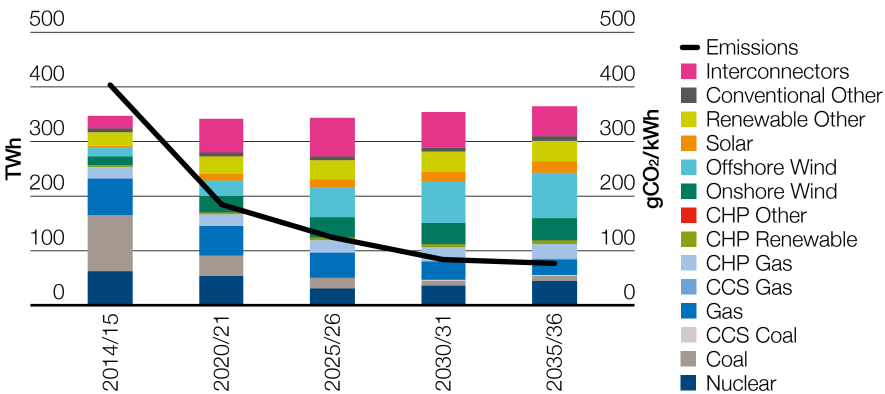


Table 2
***Slow Progression** installed capacity and output levels*

Technology	2020/21		2030/31	
	Capacity (GW)	Output (TWh)	Capacity (GW)	Output (TWh)
Nuclear	8.0	52.9	6.0	35.3
Coal	9.9	36.2	1.9	8.4
Gas	29.5	54.9	31.5	32.3
CCS	0.0	0.0	0.8	4.1
CHP	4.7	26.0	5.6	31.6
Onshore Wind	12.4	29.4	16.3	38.6
Offshore Wind	8.6	28.5	23.0	76.5
Solar	11.8	11.3	18.3	17.6
Renewable Other	6.2	32.7	8.5	36.0
Conventional Other	4.4	6.7	4.9	7.3
Interconnectors	8.4	62.9	14.2	66.1

Power supply

Focus on 2020

Our **Slow Progression** scenario has an increasing volume of renewable generation, with the deployment focused on established technologies, notably wind and solar PV technologies.

By 2020/21, solar PV and wind account for one third of power generation capacity, meeting a fifth of the annual power demand.

The deployment of solar PV increases 150% by 2020/21 as developers benefit from lower capital costs and continued financial support for this technology. This period also has a strong deployment of wind, with an additional 9GW connecting by 2020/21.

Flexible generation

The reduction in traditional forms of generation remain focused on gas and coal as the fleet comply with the IED requirements. **Slow Progression** shows a slight increase in the gas-fired generation by 2025/26, maintaining the security of supply standard. It also provides stability to the GB market and system, given the increase in the volumes of variable generation. There is a limited new build programme post 2025 as alternative low carbon technologies are connected to the electricity network given the long-term decarbonisation ambitions.

Decarbonisation agenda

The focus on the longer-term decarbonisation agenda results in the continued deployment of renewable generation out to 2035/36 with renewable generation representing 54% of power supply.

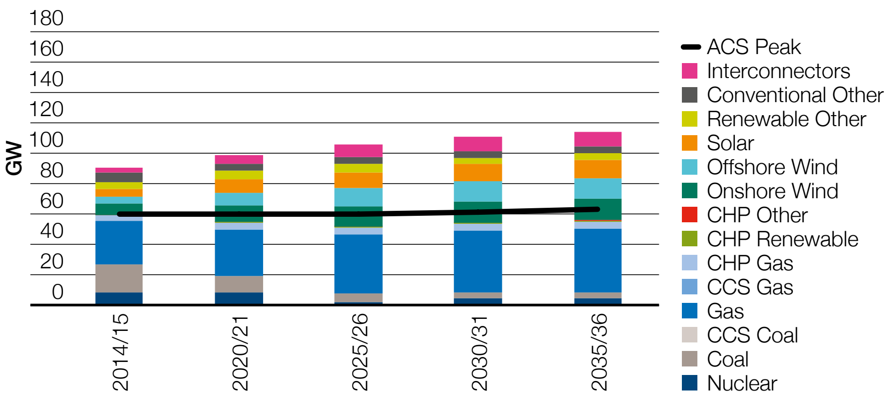
Wind and solar PV provide the largest contribution of renewable energy by 2035/36, making up 46% of the supply mix and contributing 40% of annual power demand.

The deployment of low carbon based technology strengthens from 2025. In the last 10 years of the period (2025/26 to 2035/36), our **Slow Progression** scenario sees the next generation of nuclear power stations become operational and the introduction of CCS technologies. This period also achieves greater European integration. This leads to a corresponding increase in interconnector capacity to Europe, while GB maintains its position as a net importer of electricity.

5.1.5
No Progression

Our **No Progression** scenario is dominated by established and comparatively cheaper forms of generation given the financial constraints and lack of focus on decarbonisation of the economy, as shown in Figures 60 and 61 and Table 3. The current environmental legislation impacts the sources of generation by the end of this decade.

Figure 60
***No Progression:** installed capacity*



Power supply

Figure 61
***No Progression:** power output*

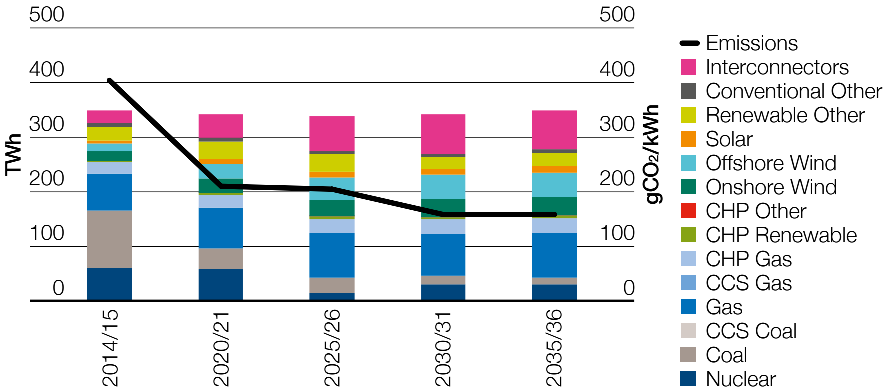


Table 3
***No Progression** installed capacity and output levels*

Technology	2020/21		2030/31	
	Capacity(GW)	Output (TWh)	Capacity (GW)	Output (TWh)
Nuclear	9.0	59.4	4.6	31.3
Coal	10.4	37.8	3.9	15.5
Gas	30.9	74.6	41.0	77.0
CCS	0.0	0.0	0.0	0.0
CHP	4.6	25.5	5.4	30.2
Onshore Wind	11.3	26.7	13.9	33.1
Offshore Wind	8.1	26.9	13.4	44.4
Solar	8.6	8.3	11.3	10.9
Renewable Other	6.0	31.9	3.7	19.9
Conventional Other	4.4	6.7	4.2	6.7
Interconnectors	6.0	43.0	9.8	72.1

Focus on 2020

Our **No Progression** scenario shows gas-fired generation as the dominant fuel source, representing ~35% of installed capacity by 2020/21. The emphasis on gas-fired generation is required to maintain the security of supply standard due to the higher levels of power demand and the closure of coal-fired power stations for environmental reasons.

Our **No Progression** scenario has an increase in the installed levels of renewable technologies out to 2020/21, particularly for solar PV and wind. This has been supported by the recent CfD round one allocation and the rush to access the ROC scheme before it closes. This has provided more certainty around the deployment of renewable generation out to 2020.

Flexible generation

Our **No Progression** scenario is shaped by established forms of generation, particularly gas-fired generation and solar PV.

By 2035/36, gas-fired generation represents ~40% of the generation capacity and ~30% of the electricity produced.

The emphasis on gas-fired generation continues out to 2035/36 providing stability to the GB electricity market and system, offsetting the closure of coal-fired generation and the decommissioning of the majority of the existing nuclear fleet.

Decarbonisation agenda

The lack of focus on the green agenda and the limited financial support available for low carbon generation results in a limited new build programme for nuclear and minimal deployment of less established technologies.

By 2035/36, solar PV and wind generation represents ~35% of the generation capacity and ~25% of the electricity produced.

Our **No Progression** scenario has no CCS and minimal marine generation as emerging technologies are hindered by the financial constraints and lack of green ambition. The deployment of low carbon generation is focused on solar PV, wind and the commissioning of a nuclear power station in the late 2020s.

Power supply

5.1.6 Consumer Power

Our **Consumer Power** scenario has a significant volumes of generation connected at a local level, facilitating emerging technologies to make their mark on the power supply landscape. Large scale generation is dominated by established technologies, as illustrated in Figures 62 and 63 and Table 4. The lack of focus on the long-term decarbonisation agenda hinders the commercial scalability of new low carbon technologies.

Figure 62
***Consumer Power:** installed capacity*

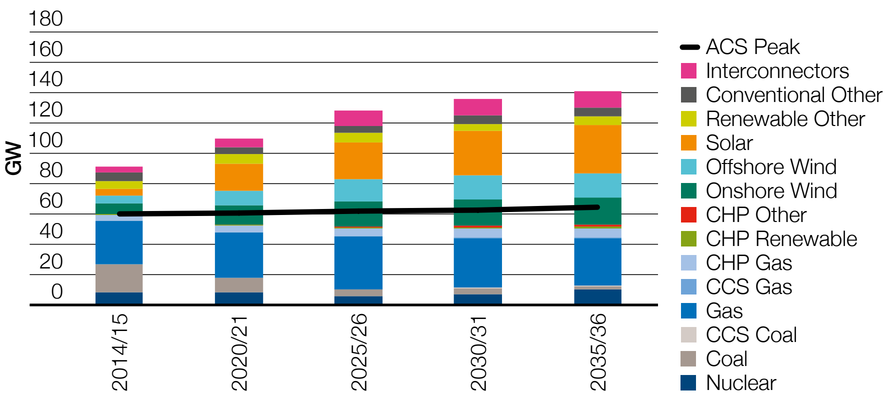


Figure 63
***Consumer Power:** power output*

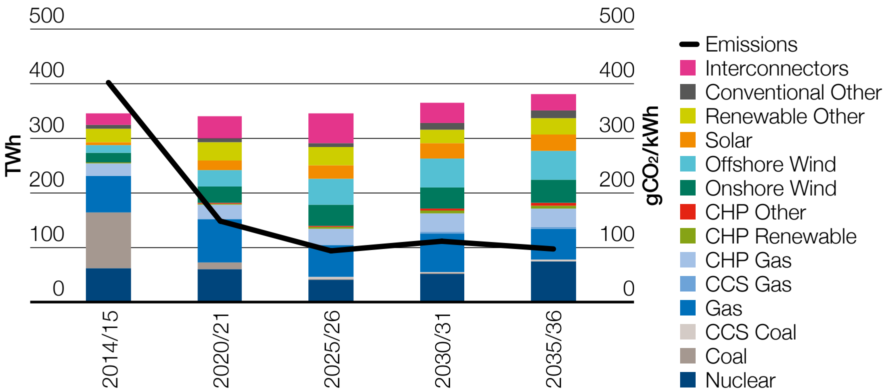


Table 4
***Consumer Power** installed capacity and output levels*

Technology	2020/21		2030/31	
	Capacity (GW)	**Output (TWh)**	**Capacity (GW)**	**Output (TWh)**
Nuclear	9.0	59.3	7.4	51.5
Coal	9.4	12.6	3.9	0.6
Gas	29.5	80.3	32.7	70.5
CCS	0.0	0.0	0.8	5.7
CHP	5.2	28.9	7.8	42.2
Onshore Wind	13.0	30.7	17.1	40.1
Offshore Wind	9.3	30.7	15.9	52.8
Solar	18.0	17.3	29.1	28.1
Renewable Other	6.3	33.3	4.9	25.2
Conventional Other	4.4	6.7	5.5	10.9
Interconnectors	6.0	40.6	10.8	38.5

Power supply

Focus on 2020

The increase of small scale generation is supported by the rapid deployment of solar PV, with installed capacity nearly quadrupling by 2020 and contributing 5% to the annual power demand. The favourable economic conditions and existing environmental legislation results in a near doubling of installed wind capacity within the next six years.

By 2020/21, small scale generation accounts for one third of the power generation capacity, meeting over a fifth of the annual power demand.

Flexible generation

Our **Consumer Power** scenario is shaped by growth in small scale generation. However traditional forms of generation (coal, gas and pumped storage) will continue to have a key role in providing flexibility to the GB electricity market and stability to the wider electricity system.

Coal and oil generation decline as environmental legislation influences how fossil fuel technologies operate under the new emission requirements. The closure of the majority of the remaining coal power stations requires additional generation to maintain security of supply, resulting in the commissioning of new gas-fired generation out to 2025/26.

By 2025/26, gas-fired generation represents ~30% of the generation capacity and ~25% of the electricity produced.

Consumer Power shows a decrease in the installed capacity of gas-fired generation by 2035/36. This is a result of the commissioning of the next generation of nuclear power stations and a decrease in power demand, offsetting the requirements for gas-fired generation.

Decarbonisation agenda

The lack of political consensus for centralised carbon reduction policy restricts the emergence of large scale low carbon and renewable technologies such as CCS and marine. These are limited to demonstration sites as commercial scalability remains unattainable. Large scale generation is dominated by established technologies such as nuclear and gas.

By 2035/36, nuclear and gas-fired generation represent 34% of generation capacity and contribute 44% of electricity produced.

The favourable economic conditions encourage the emergence of new technologies connecting to the lower voltage networks. These include generation from various waste technologies such as advanced conversion technologies and anaerobic digestion. The deployment of wind and solar PV continues, representing 46% of the generation capacity by 2035/36.

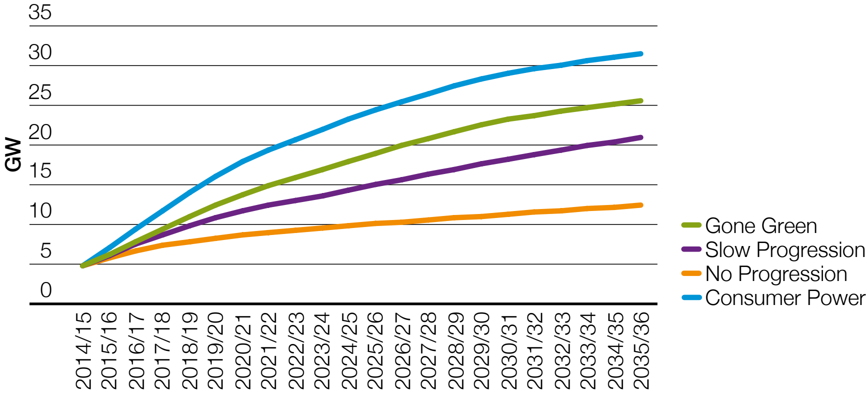
5.1.7
2020 focus: solar PV and wind

The achievement of 2020 renewable energy targets (15% of energy provided by renewable sources) is underpinned by the contribution from the power sector, with 34% of power coming from renewable technologies. The rapid deployment of renewable generation out to 2020 is led by the deployment of wind (onshore and offshore) and solar PV generation.

Solar PV
The emergence of solar PV in the GB energy landscape has been substantial (doubling over the last 12 months), as developers enter the GB market encouraged by government ambitions and support mechanisms, in addition to parallel reductions in technology costs.

Our 2015 solar PV projections, as shown in Figure 64, are based on increased stakeholder engagement with the solar industry and access to additional market information which has enhanced our knowledge for this technology.

Figure 64
Solar PV: installed capacity



Solar PV has benefited from a quicker deployment rate compared to other technologies mostly due to the planning regime and the shorter construction time. By keeping the size below 50MW, planning permission for solar PV projects are considered by the local planning authority, as set out by the Town and Country Planning Act 1990[11], rather than the Planning Inspectorate.[12]

[11] http://www.legislation.gov.uk/ukpga/1990/8/contents
[12] http://www.planningportal.gov.uk/planning/planninginspectorate – Pages 19 and 20

Power supply

So far the deployment of solar PV has been focused in the southern half of England, connecting either to the distribution network company or more locally at domestic dwellings (household roofs) as well as commercial and industrial buildings (tin roofs). There is growing evidence that the deployment of solar PV will extend further north as developers look for alternative locations and access to the electricity network.

National Grid's 2015 System Operability Framework document will assess the implication of substantial volumes of solar PV connecting to the electricity network when it is published in Q4 2015.

Solar PV sensitivity

Our solar PV figures have considered how the market has developed and expanded over the last 12 months whilst acknowledging the uncertainty regarding the sustainability of this rapid increase. Our 2015 solar PV projections were based on the information available at the beginning of January 2015. Since then the solar PV market has experienced another period of significant growth (nearly 2GW of solar PV deployed in the first quarter of 2015) as developers progressed their projects before the closure of the ROC scheme on 31 March 2015.

We recognise that our 2015 scenarios may not fully capture the true potential of the deployment of solar PV in the short to medium term. Given this development, we have reviewed our 2015 solar PV projections and have developed a solar PV sensitivity. The impact on the electricity system of increased volumes of solar PV connecting is considered in our energy balancing challenges case study and in the System Operability Framework (SOF) document.

Solar PV sensitivity

The emergence of solar PV within the GB energy landscape has been considerable over recent years. The first quarter of 2015 resulted in a significant increase in the deployment of solar PV as developers progress their projects before the closure of the RO scheme on 31 March 2015. Given this we have reviewed our 2015 solar PV scenarios and have developed a sensitivity to enable us to capture this upturn in installation rates.

The 2014/15 baseline figure has been adjusted to the official DECC figures as of 31 March 2015. The increase in the projections represents the government's continued support for solar and the potential change to the support mechanism for other technologies (providing additional funding to solar PV) and the continued reduction in technology costs.

Solar PV Installed Capacity (MW)

2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26
5,709	8,879	12,099	15,193	18,337	21,295	23,839	25,739	27,595	29,399	31,140	32,778

The impact on the electricity system of increased volumes of solar PV connecting is considered in our energy balancing challenges case study and in the System Operability Framework (SOF) document.

Wind

The significant deployment of solar PV generation over the last couple of years and the establishment of the market within GB has reduced the reliance on wind generation in achieving the 2020 climate change targets. However an additional 10 GW of wind capacity is required by the end of decade, 5 GW of which has already secured a CfD contract (including Final Investment Decision Enabling for Renewables)[13]. The pending closures of the Renewables Obligation (RO) scheme for onshore wind may encourage a strong deployment as developers strive to meet the eligibility criteria before the scheme is closed.

In our **Gone Green** Scenario, 18% of annual power demand will originate from wind by 2020/21.

The deployment of wind out to 2020/21 also has been supported by the recent CfD round one allocation. This has provided more certainty regarding how the wind profile will develop over the next few years as the country strives to meet its environmental aspirations and targets. As shown in Figure 65, there is very little divergence between our 2015 scenarios out to 2020/21.

Figure 65
Wind: onshore and offshore installed capacity

Wind deployment rates

Our stakeholders have asked whether the deployment rates, as depicted by our scenarios are credible given the current status of the projects. We have analysed whether the wind deployment rates for the period out to 2020 as shown by our **Gone Green** scenario are plausible given the important role which the technology has in the achievement of the 2020 renewable energy target.

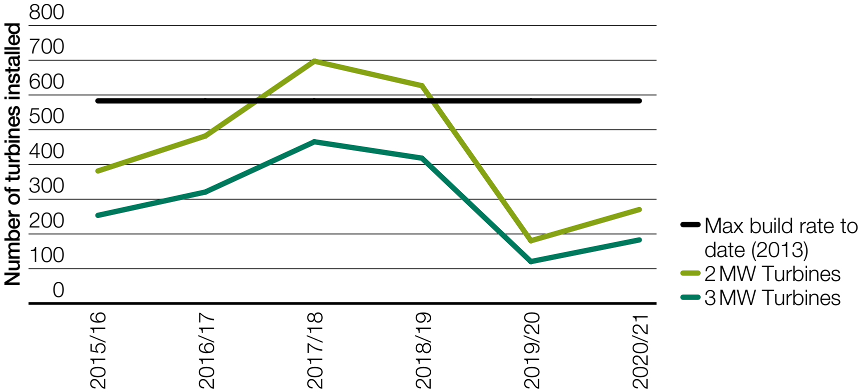
Onshore wind

The annual onshore wind deployment rates as depicted by our **Gone Green** scenario is shown in Figure 66. For 2017/18 and 2018/19 the amount of additional capacity exceeds what we have previously seen installed annually in GB. This analysis is based on the installation of 2 MW turbines which used the average size turbines deployed in 2013 when the maximum installation of onshore occurred.

[13] https://www.gov.uk/government/publications/increasing-certainty-for-investors-in-renewable-electricity-final-investment-decision-enabling-for-renewables

Power supply

Figure 66
***Gone Green:** onshore wind deployment*

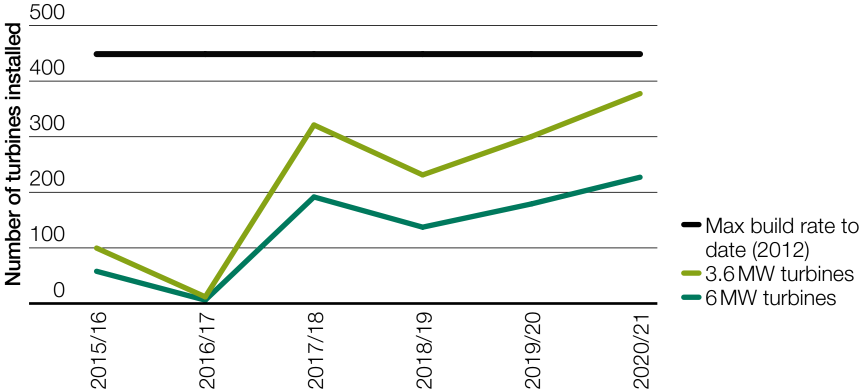


Since then technology advancement has seen the average size increase to 3MW. If this larger size is used for all onshore turbine installed going forward, then the number of actual turbine to be installed out to 2020 falls below the 2013 high as shown in Figure 66. With this increase in turbine size, the existing supply chain seems quite capable of supporting the level of additional onshore capacity required.

Offshore wind

For offshore wind, the largest annual increase in capacity occurred in 2012 when 1.6GW was installed. This is above the required annual threshold for turbine deployment as depicted by our 2015 **Gone Green** scenario, as illustrated in Figure 67. This maximum installation rate was achieved with an average turbine size of 3.6MW. Since then technology advancement has seen the average size increase to 6MW. If this larger turbine size is used for all offshore wind installation going forward then the number of turbines to be installed out to 2020, to meet the required capacity, greatly reduces.

Figure 67
***Gone Green:** offshore wind deployment*



Average offshore wind turbine sizes to be installed in the next six years are over 66% larger than the turbines sizes installed in 2012 (6 MW as opposed to 3.6 MW).

Our analysis indicated that it is possible to achieve our **Gone Green** wind deployment rates given recent advancement in turbine technology. However other parts of the supply chain will have their role to play in making **Gone Green** a reality, particular the planning process, access to financial support and certainty and clarity on government policy e.g. publication of strike prices for 2019/20 and 2020/21.

Power supply

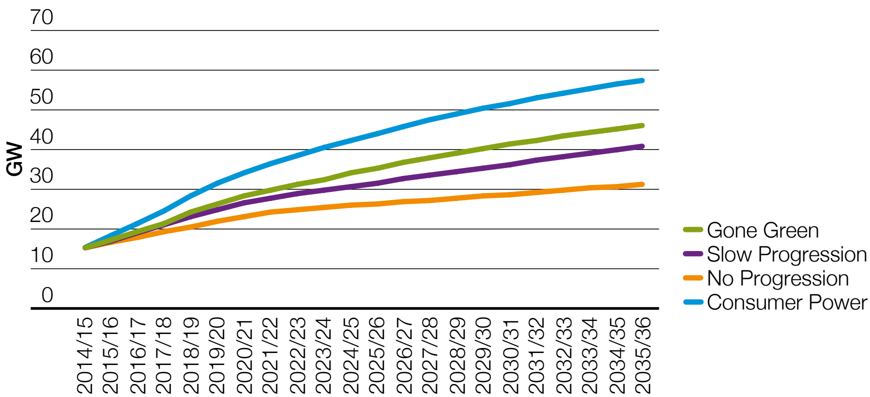
Chapter five

5.1.8
Distributed and micro-generation

Generation connecting to the distribution networks, domestic dwellings and commercial and industrial buildings has been an area of significant growth in recent years, encouraged by government support for low carbon technologies.

All of our scenarios consider a potential growth in small scale generation, starting from ~15 GW in 2014/15 increasing to ~31 GW in **No Progression** and to ~57 GW (40% of total installed generation capacity) in **Consumer Power** as shown in Figure 68. The growth in small scale generation focuses on renewable sources with particular emphasis on solar PV.

Figure 68
Distributed and micro-generation: installed capacity



The development of distributed and micro-generation is an important part of our power supply scenarios. It will influence the wider electricity system as it reduces the demand on the National Electricity Transmission System (NETS), potentially resulting in energy balancing challenges (please refer to case study) and system operability issues.

Distributed generation

All of our distributed generation scenarios consider the potential for the development of generation plant connected to or making use of the distributed networks.

Our distribution scenarios consider a wide variety of technologies both fossil and renewable as shown in Table 5.

Distributed generation is defined as 'generation connected to the distributed networks which is ≥1 MW in size, up to onshore transmission areas mandatory connection thresholds'.

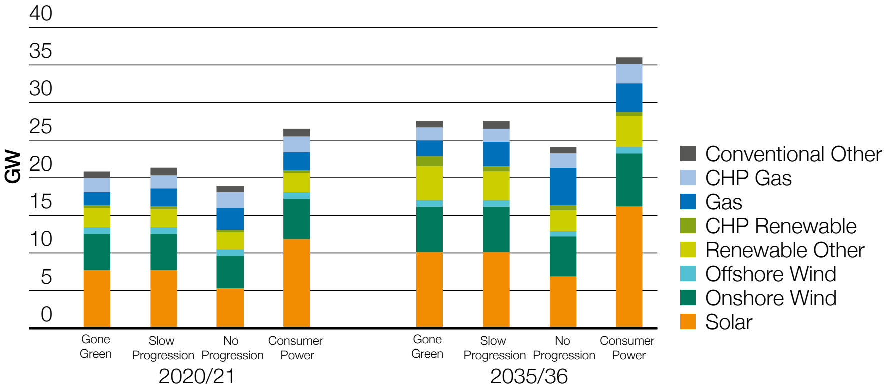
Table 5
Distributed generation technologies

Fossil	Renewable		
Coal CHP	Anaerobic Digestion CHP	Anaerobic Digestion (AD)	
Gas CHP	ACT CHP	Advanced Conversion Technology (ACT)	Solar
CCGT	Biomass CHP	Biomass	Tidal
Open Cycle Gas Turbine (OCGT)	Geothermal CHP	Geothermal	Wave
Diesel Engines	Sewage CHP	Landfill Gas	Onshore Wind
Fuel Oil	Waste CHP	Waste	Offshore Wind

We have developed three data sets which have different deployment rates (low, medium and high) for each of the technologies. These have been applied to our scenarios as depicted by their narrative and assumptions. **Consumer Power** has the highest levels of distributed generation whilst **Gone Green** and **Slow Progression** scenarios are dominated by renewable generation. Our scenarios incorporate the 2018/19 CM auction results for small scale generation and consider IED compliance for applicable plant.

Power supply

Figure 69
Distributed generation: installed capacity



834 MW of small scale OCGT and reciprocating engines were allocated 2018/19 CM contracts.

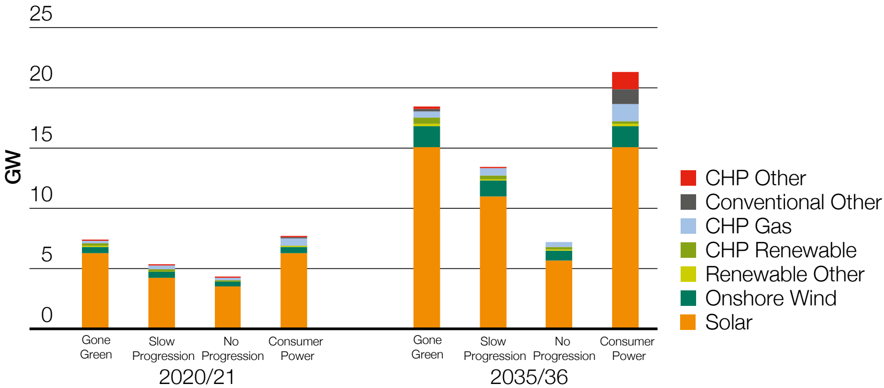
Figure 69 shows our distributed generation scenarios at 2020 and 2035.

The deployment rates for distributed generation have been developed from a variety of different information sources: from government data to information provided from trade associations and electricity distribution networks. There is currently no centralised source of all generation connected to the distribution networks. Given the limited visibility of future distributed generation deployment at an individual plant level, the scenarios have focused on the potential uptake of particular technologies.

Micro-generation

Our micro-generation scenarios consider the potential for the deployment of sub-1 MW generation. Our 2015 scenarios consider an extended set of technologies: solar PV (installed on domestic dwelling as well as commercial and industrial buildings), wind, hydro, CHP (gas, biomass, biogas and micro) and fuel cells. Figure 70 shows our installed micro-generation scenarios at 2020 and 2035.

Figure 70
Micro-generation: installed capacity



Our scenarios consider the potential uptake of micro-generation and how new technologies could emerge. This is dependent on favourable economic conditions and support mechanisms providing the desirable market conditions.

Power supply

Method

Power generation capacity

Our power supply scenarios are developed using a deterministic approach. The scenario narrative and assumptions provide the uncertainty envelope that determines the emphasis placed on the different types of generation technology within each scenario. The emphasis placed on a particular technology is determined by a number of factors such as market intelligence, government policy and legislation, project status and power station economics. The generation backgrounds are then developed to meet the security of supply standard for each of our power demand scenarios and stay within the budget as specified by the LCF.

Power generation output

The generation output from each power supply source is determined from the respective installed capacity and cost of generation. For large scale generation this is determined by the Short Run Marginal Cost (SRMC) at power station level. For each half hour of the year the available power stations are dispatched in line with their SRMC. Starting with the plant with the lowest SRMC, the generation is dispatched until the demand threshold for that half hour is met. The generation output is then aggregated at an annual level. Technologies can be broadly split into three tranches: zero SRMC, low SMRC and fossil fuel plants (high SMRC):

- Zero short run marginal costs – the first tranche of technologies have zero SRMC and typically include renewable technologies such as wind and marine. They are assumed to operate whenever they are able to e.g. when the wind is blowing. Each technology has an assumed load factor, as shown in Table 6.

Table 6
Renewable technology average annual load factors (transmission connected)

Technology	Average Availability
Onshore Wind	28%
Offshore Wind	38%
Marine	22%
Solar PV	11%
Hydro	33%

- Low short run marginal costs – the next tranche of technologies have either very low SRMC or receive income from another revenue stream. They include nuclear, biomass, CHP and CCS technologies. Each technology has an assumed availability figure which represents the percentage of time the power station could run for if required, as shown in Table 7.

Table 7
Low carbon technology average availabilities (transmission connected)

Technology	Average Availability
Biomass	70%
CHP	60%
CCS	85%
Nuclear	76%

- Fossil fuel plant (high SRMC) – the final tranche of technologies are fossil fuel plants. These include coal, gas and oil fuelled plant. The SRMC of these power stations is primarily determined by the cost of fuel (see chapter 3 for fuel price details) and CO_2 emissions.

Interconnectors

5.2 Interconnectors

For each scenario, we produce interconnector capacity levels and flows for peak and annual periods. This feeds into our power demand and generation modelling. The capacity levels for FES 2015 have increased from FES 2014 due to greater regulatory certainty as a result of Ofgem's cap and floor regime for interconnectors. For our annual flows, GB is a net importer of power, with the exception of Gone Green from 2031/32. For our peak flows, we have greater imports across all scenarios at times of GB system stress.

Key statistics

- The current interconnector capacity in GB is 3.8GW. For **Gone Green** in 2020/21 the capacity level is 10.8GW. This would meet the EU 2020 target for interconnection.
- Capacity levels in 2034/35 range from 9.8GW for **No Progression** to 17.7GW for **Gone Green**.
- GB remains a net importer. In 2020/21 the net import annual flows range from 39TWh for **Consumer Power** to 68TWh for **Gone Green**. From 2031/32, for **Gone Green**, GB becomes a net exporter reaching net exports of 11TWh by 2035/36.
- In 2020/21, the net peak flows range from imports of 2.2GW for **No Progression** to 4GW for **Gone Green**. In 2035/36 the range is from 3.5GW imports for **No Progression** to 6.5GW for **Gone Green**.

Interconnectors

5.2.1
Capacity levels

Figure 71
Capacity level comparison in GW

	Gone Green		Slow Progression		No Progression		Consumer Power	
	FES 2015	FES 2014	FES 2015	FES 2014	FES 2015	FES 2014	FES 2015	FES 2014
2020	10.8	6.0	8.4	6.0	6.0	5.0	6.0	5.0
2025	15.7	7.4	12.2	7.4	8.4	6.0	9.8	7.4
2030	17.7	11.8	14.2	8.4	9.8	7.4	10.8	7.4
2035	17.7	11.8	14.2	11.8	9.8	7.4	10.8	7.4

Our capacity levels have increased considerably from FES 2014 and the table above offers a comparison. The current interconnector capacity level for GB is 3.8GW and for **Gone Green** in 2020, the level is 10.8GW. The increase over the next five years is due to Ofgem's decision to introduce the cap and floor regime in 2014 and the progression of those projects. The introduction of the regime has de-risked investment decisions in new interconnectors by placing a floor on investment losses. There is also a cap to protect consumers.

The EU has non-binding interconnector capacity targets for all members[14], which are set based upon a percentage of generation installed within that country. The GB non-binding target is currently 10% by 2020 which is approximately 10.2GW of interconnector capacity. The EU is looking into raising the target to 15% for 2030 which is approximately 22.6GW[15]. In **Gone Green** we have assumed that Ofgem will use the cap and floor regime to support the delivery of the 2020 capacity target.

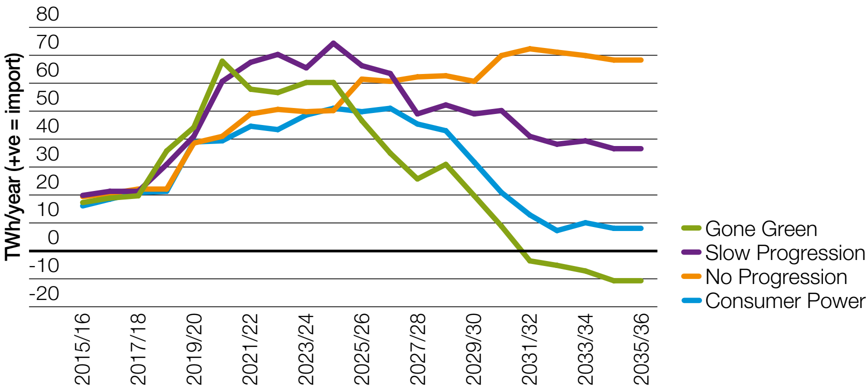
For 2030 **Gone Green** falls short of the capacity target due to a shortage of projects in the pipeline. This highlights the potential opportunities for additional interconnector projects in the future.

The highest interconnector capacities are in **Gone Green** followed by **Slow Progression**, **Consumer Power** and **No Progression**. Higher wind generation in **Gone Green** and **Slow Progression** creates a greater need for interconnectors to compensate for variable levels of generation. Greater prosperity means more money available to develop interconnectors in **Consumer Power** than **No Progression**.

[14] http://europa.eu/rapid/press-release_MEMO-15-4486_en.htm

[15] Includes micro and distributed generation

Figure 72
Net annual flows



In the short term, annual imports rise rapidly in line with the increase in capacity. Across all four scenarios GB remains a net importer of electricity due to the price differential with connected countries until the early 2030s. The carbon price support is a major factor in this price differential. Additional levels of both nuclear and variable generation increase the times when price differentials favour exports. This results in lower net imports from the mid-2020s onwards in three of the scenarios, with a shift to a net export position in **Gone Green** from 2031/32. Conversely, in **No Progression**, which has much lower levels of variable generation than **Gone Green**, net imports continue to increase until the 2030s. **Slow Progression** and **Consumer Power** have similar levels of exports. **Slow Progression** has more imports due to a higher gas price which results in higher net imports for this scenario compared to **Consumer Power**.

The **Gone Green** analysis highlights the benefits of greater interconnection in providing access to lower cost low carbon energy across Europe.

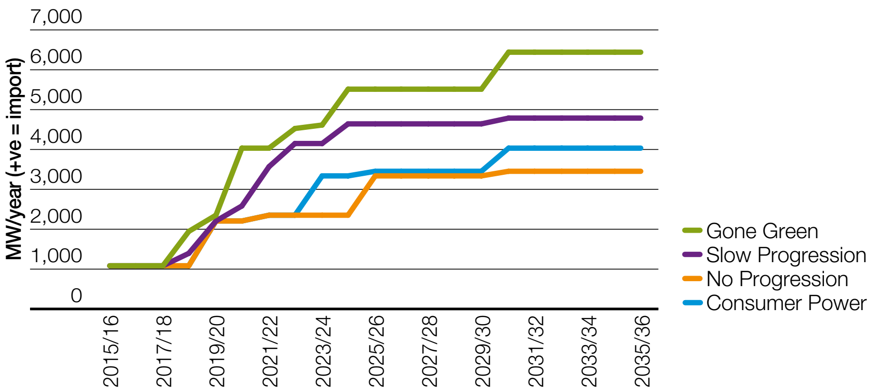
Interconnectors

5.2.2
Peak flows

Interconnector flows at peak demand levels will vary greatly depending on the level of generation and demand across Europe. The figures produced for FES 2015 show the typical flows that could be expected when the GB capacity margin is low.

This year we have changed our peak analysis following stakeholder feedback. Last year we assumed net float at peak with exports to Ireland exactly offset by imports from the continent. For FES 2015, the increased capacity in our scenarios enables much higher imports from the continent when we need it. We have retained exports to Ireland.

Figure 73
Aggregate peak flows



For FES 2015 the peak flows are the typical levels expected at times of low or negative GB capacity margin. However, actual flows at times of ACS peak demand could differ significantly from these figures. For example, if there was high wind generation we may even see net exports, particularly in the **Gone Green** scenario.

We calculated our peak flows by multiplying our capacity levels by assumed de-rating factors. These factors were based on Pöyry's analysis of historical de-rating factors for DECC[16]. This report recommended conservative values to act as a floor for the factors to be applied in the 2019/20 capacity market auction. Therefore, for FES, we have made a number of adjustments which are explained in more detail in the method section below.

Figure 73 reflects a correlation of greater net peak imports depending on the level of capacity in the scenario. **No Progression** sets the bottom of the range followed by **Consumer Power**, **Slow Progression** and **Gone Green** with the highest imports. Peak imports do not rise as fast as capacity because we have assumed that generation will not increase in line with interconnection. We have therefore applied a reduction to the peak imports we could expect from each additional interconnector to a country that is already connected to GB. This has the biggest impact on **Gone Green** and **Slow Progression**.

Our peak flows have a direct impact on the generation capacities in our scenarios. For instance, in **Gone Green**, imports of over 6GW from 2030 will reduce the level of generation capacity required in our scenario to meet security of supply standards.

[16] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/404337/Final_historical_derating_of_IC_poyry_report.pdf

Interconnectors

Method

Capacity levels

Our capacity level analysis is driven by stakeholder engagement, Ofgem's cap and floor regime and the non-binding EU targets. Any project without a final investment decision is considered to be uncertain and the scenarios are used to reflect this uncertainty. We have included a number of the conceptual Projects of Common Interest produced by ENTSO-E's Ten-Year Network Development Plan, where feasibility studies and Transmission System Operator (TSO) sponsors are in place. These projects are identified to have socio-economic benefits but may not yet be fully viable or backed by investors/developers. Interconnector projects were grouped into short, medium and long, based on the length of cable. France, Belgium, Netherlands and Ireland were in the short group, Denmark and Norway in the medium group and Iceland and Spain in the long group. Long links are only included in **Gone Green**. **No Progression** was limited to a conservative assessment of the near-term projects up to the 2020 cap and floor projects, under the scenario assumptions of less prosperity and investor uncertainty. Further variation between the scenarios was created by staggering and delaying implementation of interconnector projects. The order of earliest to latest being **Gone Green**, **Slow Progression**, **Consumer Power** and **No Progression**.

Annual flow modelling

Annual flows were modelled using National Grid's Electricity Scenario Illustrator (ELSI)[17], an economic model used for assessing transmission investments. This is a significant development from FES 2014, and part of a series of improvements. We are looking to further develop our tools and capabilities in this area in our expanding role as EMR Delivery Body and under the Integrated Transmission Planning and Regulation (ITPR) project.
To enable ELSI to model interconnector flows, each connected country is represented as a single node with a static price. There are 12 prices in the year representing 3 seasons (winter, summer and spring/autumn) and 4 time periods. These European prices were purchased from Baringa, who ran their European model using their scenarios mapped to National Grid's FES 2014 scenarios and adjusted for FES 2015 fuel price assumptions. Interconnector modelling is the first stage of FES modelling so FES 2014 demand and generation figures had to be used, alongside FES 2015 interconnector capacities and fuel price assumptions.

[17] http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/Electricity-Ten-Year-Statement/

Peak flow analysis

Our peak flows were calculated by multiplying the capacity levels for each scenario by assumed de-rating factors. These de-rating factors reflect the amount an interconnector is expected to be importing electricity to GB when it is required to provide security of supply. The variation in peak flows is driven by the interconnector capacity assumptions. The interconnector de-rating factors were based on Pöyry's report to DECC on historical interconnector de-rating factors[18]. This report recommended conservative values to act as a floor for the factors to be applied in the 2019/20 capacity market auction. Therefore, for FES, we have made a number of adjustments which are explained in more detail below:

- We have used the same de-rating factors for all scenarios except for one adjustment.
- We reduced the de-rating factors by 50% for each new interconnector added to countries that are already interconnected with GB. We have assumed that generation capacity will not increase in line with additional interconnector capacity. The impact is different de-rating factors for each scenario for France and Norway with **Gone Green** affected most significantly, due to the highest number of interconnectors, whilst there is minimal impact for **No Progression**.
- We based France on 2012 and 2013 only, increasing the de-rating factor from 29% to 62%. This is because the report contained a wide range for France depending on the period and type of analysis and we felt that the influence of market coupling on the 2012 and 2013 figures made the higher number more appropriate for this analysis.
- We reduced the de-rating factors for Belgium, Norway and Netherlands to adjust for technical availability. The 5% reduction value comes from the long cable (project 2) figures in the Sinclair Knight Merz (SKM) report to Ofgem[19].
- We applied a de-rating factor of 90% to Iceland reflecting an assumption of very high commercial availability tempered by an increased risk of technical unavailability due to the length of the line, and the potential risk of geological activity affecting the connection.
- For all scenarios we set peak exports to Ireland at 750 MW initially. This is in line with recent experience and our annual flow analysis. We reduced exports to 500 MW from 2019/20 onwards to reflect greater market efficiency and full market coupling following completion of the north/south transmission link.

[18] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/404337/Final_historical_derating_of_IC_poyry_report.pdf

[19] https://www.ofgem.gov.uk/ofgem-publications/59247/skm-report-calculating-target-availability-figures-hvdc-interconnectors.pdf

Gas supply

5.3
Gas supply

Our gas supply scenarios include a wide range of possible supply patterns. Production from the UK's indigenous resources is aligned to the scenario axes of green ambition and prosperity. The gas market provides enough gas from Europe and beyond to make up the difference between indigenous supply and demand.

In response to positive stakeholder feedback we have once again chosen to represent a large part of our imported gas as 'generic import', which can be any mix of liquefied natural gas (LNG) or continental gas delivered through the IUK[20] and BBL[21] interconnectors. Although no new shale gas wells have been drilled in the last year, progress has been made in planning. We have included substantial development in **Consumer Power**, which combined with strong development on the UK continental shelf, drives imports down to below 40% of total supply in the mid-2020s.

As demand is lower in all scenarios than the maximum levels seen in recent years we do not see a requirement for new infrastructure simply to ensure that supply matches demand. This does not in any way preclude the possibility that new storage or import facilities may be built for sound commercial reasons.

Key statistics

- UKCS production peaks in 2018 in all scenarios, contributing between 39% and 49% of total supply in Slow Progression and Consumer Power respectively.
- Shale gas production ranges from zero in Slow Progression and Gone Green to 32 bcm/year in Consumer Power. This requires the development of 100 sites each with 10 vertical wells and 40 lateral wells.
- Import dependency rises to around 90% in Slow Progression by 2035. This could mean around 170 LNG deliveries throughout the year.

[20] Interconnector UK: an import and export pipeline between Bacton and Zeebrugge

[21] An import pipeline from Balgzand (Netherlands) to Bacton

5.3.1
Gas supply in each scenario

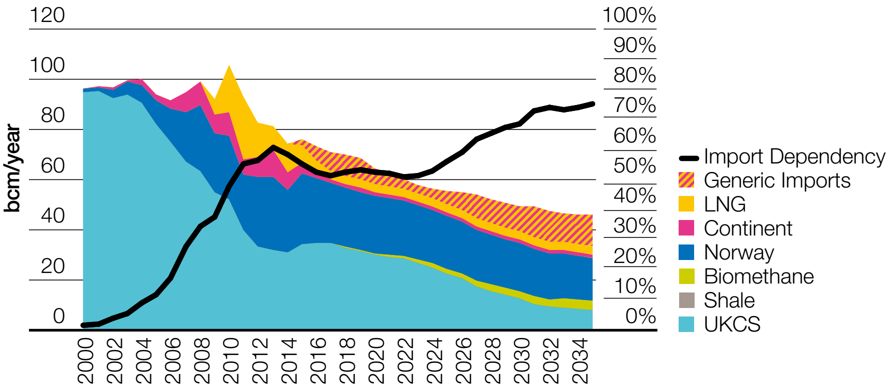
Gone Green

In **Gone Green** gas demand falls from 2015 onward and is the lowest in any of the scenarios. Production from the UKCS in this prosperous scenario is high in the early years, but declines later as investment is focused more on perceived greener technologies.

Some of our stakeholders expressed the view that in a world with high green ambition, especially a prosperous world, protest groups opposed to shale gas development would be well organised and well funded. In recognition of this, the government policy in **Gone Green** includes further restrictions on shale development and as a result we have not included any shale gas in the scenario. Injection of biomethane is currently supported by the Renewable Heat Incentive. In this scenario, with high green ambition, government policy increases support for the technology. Biomethane production is at its highest in this scenario, though the total volume is still only 4 bcm/year.

Although the UKCS production is only moderate, and there is no shale gas, demand is so low that the requirement for imported gas is also low up to the mid-2020s. Supplies from both Norway and the generic import are at the bottom end of our range of expectations. By 2035 however, the continuing decline in UKCS production means that import dependency rises to around 80%. The annual supply pattern for **Gone Green** is shown in Figure 74.

Figure 74
*Annual supply pattern in **Gone Green***



Gas supply

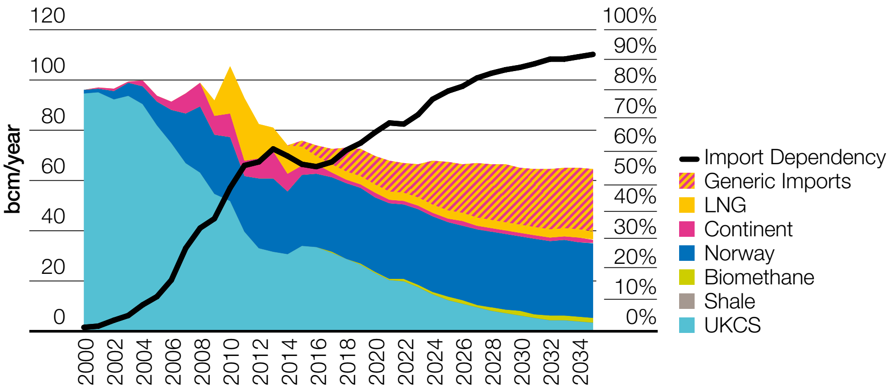
Slow Progression

In **Slow Progression**, gas demand is slightly higher than in **Gone Green**. In this scenario, conditions for development of UK indigenous production are poor. The economy is growing slowly and there is additional taxation on offshore production. As such, UKCS development is lower in **Slow Progression** than in any other scenario.

Government policy continues to support biomethane but not shale gas. In line with the green ambition in this scenario, the limited investment that takes place is concentrated on greener technologies. This results in some development of biomethane, but not shale gas. The limited indigenous production leaves room for the highest level of imports, with both Norwegian gas and the generic imports at the top end of our expected range. The generic import could be supplied in full by either LNG or pipeline gas from the continent with the existing infrastructure, though the volumes are sufficiently high that new capacity may be attracted to the market.

Our Gas Ten Year Statement document lists a number of proposed import projects that are progressing through planning but have not yet reached final investment decisions. It is therefore conceivable that some of these might move forward. The annual supply pattern for **Slow Progression** is shown in Figure 75.

Figure 75
*Annual supply pattern in **Slow Progression***

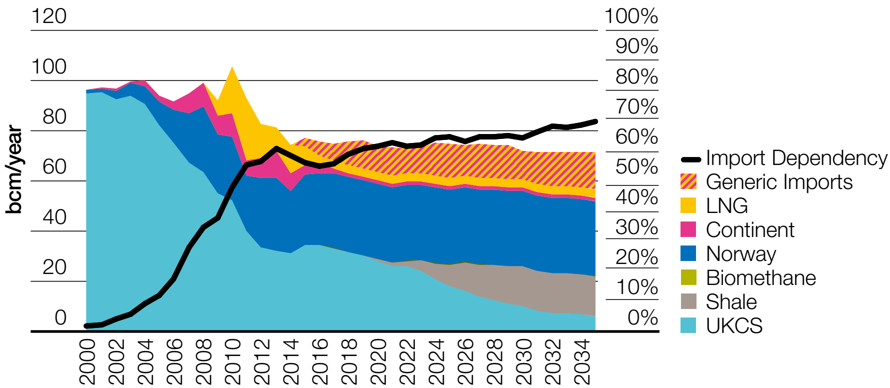


No Progression

In **No Progression** gas demand is higher than **Slow Progression**. In 2016 and 2017 demand is higher than in any other scenario. Government policy in **No Progression** is similar to today, so there is no additional taxation on offshore production. There is no extra support for, or supplementary restrictions on, shale gas production. Additionally there is no additional support for biomethane over and above the current Renewable Heat Incentive. The poor economic conditions rather than policy limit developments in **No Progression**.

There is not sufficient money available to encourage production in the more marginal UKCS fields, and shale gas and biomethane development is similarly restricted. The requirement for imported gas is relatively high with supplies from Norway at the top end of our expectations and the generic import also in the upper part of the expected range. The annual supply pattern for **No Progression** is shown in Figure 76.

Figure 76
Annual supply pattern in ***No Progression***



Gas supply

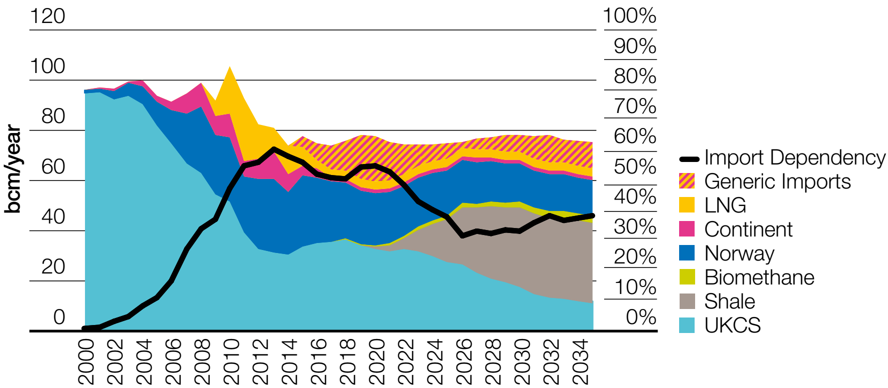
Consumer Power

In **Consumer Power** gas demand is high throughout the period, and from 2018 onwards is higher than in all the other scenarios. In this scenario the economy is growing and there is money available for investment. Government policies support offshore production with lower taxation and support shale gas with more favourable regulation.

Biomethane is still supported at the current level but, as this is a scenario with lower green ambition, no new support is offered. The positive investment climate and an environment with high technical innovation lead to the greatest production from the UKCS, with fields being developed that are too challenging in other scenarios. Shale gas development is similarly well supported, with production starting in around 2020 and rising to around 32bcm/year by 2030. The high level of indigenous production means that the requirement for imported gas is low. Both Norwegian supplies and the generic import are at the bottom of our range of expectations.

The total import dependency falls to around 32% in the mid-2020s before rising to 39% by 2035. The annual supply pattern for **Consumer Power** is shown in Figure 77.

Figure 77
Annual supply pattern in ***Consumer Power***



5.3.2 UK continental shelf

Our UKCS projections continue to be based on information provided by producers through an annual process which is run in conjunction with Oil & Gas UK[22], combined with market intelligence and our own analysis. Following many years of decline, production in 2013 and 2014 was slightly higher, a trend which continues for a few years in the two more affluent scenarios, **Consumer Power** and **Gone Green**, before it declines again. In **Slow Progression** and **No Progression** supplies do not rise above the 2015 level and decline from 2017 onwards. Differences between the four scenarios are inevitably quite small in the first few years as our projections are based on fields that are already in, or close to, production.

In later years the UKCS sees greater expansion in **Consumer Power** and **Gone Green**. The growing economy and a high level of technical innovation support development of fields that are too difficult or too expensive for the poorer economic conditions of **Slow Progression** and **No Progression**.

We have not included a separate chart for UKCS production as the volumes can be seen in context in the annual supply patterns for each scenario, Figure 74 to Figure 77.

[22] Oil and Gas UK is a representative body for the UK offshore oil and gas industry.

Gas supply

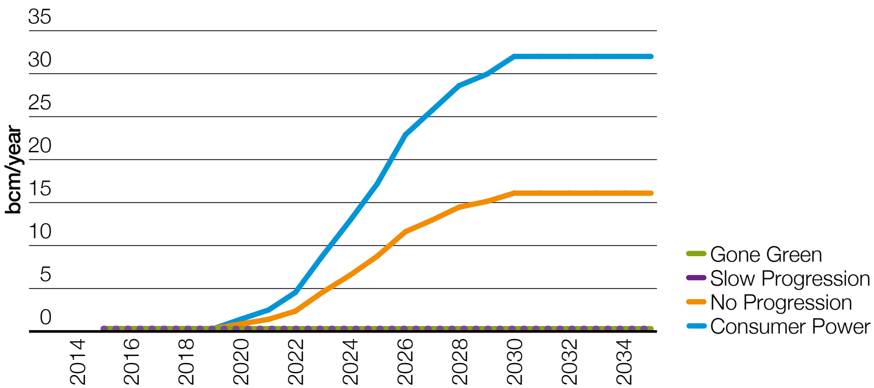
5.3.3
Shale gas

In the last year there has been continued financial support for shale gas development with a number of investments made by large gas and chemical industrial companies. The government has also promised to support the UK shale industry through tax incentives, sovereign wealth funds and changes to underground access rights. Additionally the government has promised community benefit packages and funding to help develop a national college specialising in onshore oil and gas.

In Scotland, a moratorium on planning permissions for all unconventional oil and gas projects was announced in January 2015. This is due to be maintained until a full public consultation is completed on the extraction of shale gas.

Results of the 14th onshore oil and gas licencing round are expected in the second half of 2015. A few test wells have been drilled in the North West of England, and planning applications have been submitted for further test wells in England. Although there has been some progress in a number of areas, the industry is still waiting for the results of the test wells. Following discussions with our stakeholders we have based our 2015 projections on last year's analysis and used a wide spread for shale gas production. These range from no development in **Gone Green** and **Slow Progression** to a peak of 32 bcm/year in **Consumer Power**, as shown in Figure 78.

Figure 78
Shale gas production



The high shale case represents a significant part of the total gas supply in **Consumer Power**, as shown in the annual supply pattern in Figure 77. Some of our stakeholders have asked what will be required to get to this level of production so we have outlined some indicative milestones that will be needed:

Milestones on the way to 32 bcm/year of shale

To achieve 32 bcm/year of shale gas by 2030 the following need to be in place:

- Cuadrilla are granted final planning permission this year (2015)
- Favourable results from test wells (2016)
- Apply for planning applications, licences and environmental permits for further shale gas wells (2016)
- Drilling of additional wells (2016/2017)
- Monitor flows for 12-18 months to assess volumes produced. Results favourable (2017/2018)
- Apply for production licences and environmental consents for shale gas wells (2018)
- Monitor seismic and environmental conditions for 12 months (2018/2019)
- Commercial production starts (2020)
- 100 sites (known as 'pads') (10 vertical wells 40 laterals per pad) developed to get to 32 bcm by 2030.

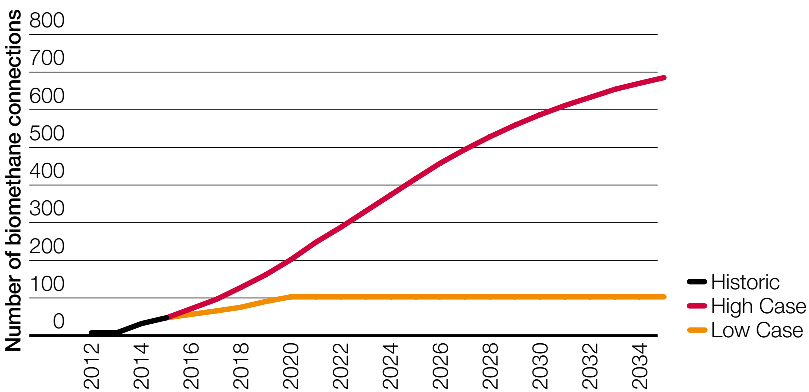
Gas supply

5.3.4
Biomethane

Injection of biomethane into the network is supported under the non-domestic RHI and contributes to meeting renewable energy targets. There is continuing interest in the field, and both the number of biomethane projects and the volume of gas entering the network from those projects has increased substantially in the last 12 months.

Our projections are based on the latest information available to us on the number of biomethane connections and flow rates. They show an increase of around 10% since our 2014 scenarios with a high case in **Gone Green** of around 4 bcm/year in 2035. The volume of biomethane can be seen in context in the annual supply patterns for each scenario, Figure 74 to Figure 77. The total number of connections is shown in Figure 79.

Figure 79
Total biomethane connections



5.3.5
Coal bed methane

We have removed the contribution from coal bed methane (CBM) from our 2015 scenarios, as we expect some of the CBM developments to be delayed or cancelled if shale gas applications are approved. We also expect gas produced from those CBM sites that are not delayed or cancelled to be used for on-site power generation rather than being connected to the gas network.

5.3.6
Norway

In making our projections of supplies of Norwegian gas to GB we consider two different aspects: total production of Norwegian gas and the proportion of the total that comes to GB. Our projections of production are based on data on reserves for the North Sea, Norwegian Sea and Barents Sea, held by the Norwegian Petroleum Directorate. We additionally use external forecasts for some key individual fields. A range of possible production is created by assuming different success rates for developing new fields. In 2014, GB received approximately 25 bcm of Norwegian exports. Supplies of Norwegian gas to GB in our scenarios are not pre-determined, but are derived as part of the process of matching supplies to demand. The difference in Norwegian flows between scenarios is not as marked as for other imported gas. This is based on stakeholder feedback and also reflects the fact that there are fewer opportunities for Norwegian gas to find alternative markets than for other import supplies.

We have not included a separate chart for Norwegian supply as the volumes can be seen in context in the annual supply patterns for each scenario, Figure 74 to Figure 77.

Gas supply

5.3.7
Imported gas: liquefied natural gas (LNG) and continental gas

In all scenarios we assume that there will be at least a minimum flow from both LNG and continental gas. These minimums are defined by boil-off[23] gas for LNG, contractual minimums for continental imports and our assessment of any additional flows which could be expected under the conditions in the scenarios. The remainder is assigned to generic imports which could be made up of either continental imports or LNG. The nature of the generic import depends on the world gas market and can be influenced by a wide range of factors. For example, the expected restarting of nuclear power stations in Japan reducing the Japanese demand for LNG imports and releasing more LNG into the market, or drought conditions in South America reducing hydro-generation and increasing the requirement for LNG imports.

5.3.8
Storage

Gas storage plays a useful role in supporting security of supply and providing flexibility in the operation of the gas network. Two new medium range storage projects were completed in the last year. However the economics, and in particular the price spread between winter and summer, have limited activity in the development of new seasonal storage.

Storage plays an important role throughout the year. During the winter, storage can provide baseload supplies through the seasonal storage sites. All sites can also provide cover at periods of high demand. The sites are active throughout the year, optimising injection and withdrawal patterns to help balance supply and demand.

[23] A small amount of gas continually boils off from LNG storage tanks. This helps to keep the tanks cold.

5.3.9
Peak gas supply

There is sufficient capacity in all scenarios to meet the peak demands, assuming that:
- Indigenous gas production (from UKCS, shale and biomethane) operates with a 20% swing factor
- All existing capacity remains available throughout the period.

In the assessment of peak gas supply, we compare peak demand with the maximum supply potential from all sources. For imports and storage this is defined by the maximum technical capacity of all existing[24] sites and those who have taken a final investment decision. We also assume these remain available for the duration of the scenarios unless an official announcement has been made that the site will close.

For the UKCS, the peak supply potential is determined by the level of annual production in each scenario with a swing factor applied. This reflects the fact that production is generally not the same on all days of the year but tends to be lower in summer, when maintenance is usually planned. Based on observations over recent years we have used a swing factor of 20%, indicating that production on a winter day is 20% higher than the annual average. There is little data to determine how shale gas or biomethane will behave at peak. We expect that maintenance will still be concentrated in the summer, so have used the same approach as for the UKCS, applying a 20% swing factor to the annual supplies.

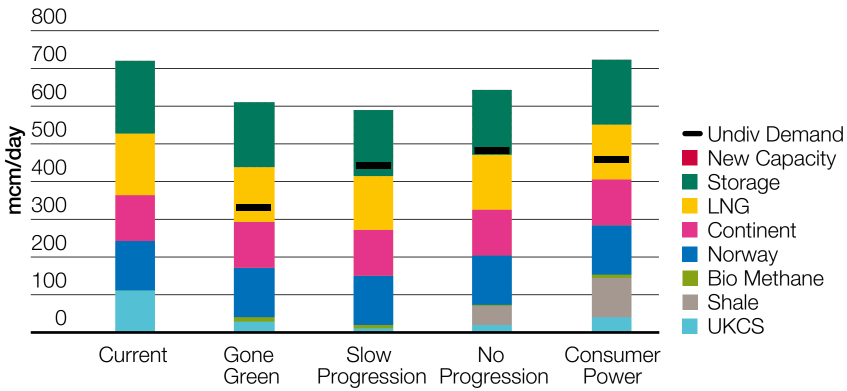
The peak supplies follow a similar trend to the annuals. In both **Gone Green** and **Slow Progression** the potential peak supply falls as UKCS production drops and there is no development of shale gas. **No Progression** also falls as the limited shale development does not replace the fall in UKCS. **Consumer Power** ends the period with available supplies slightly higher than today. In all of our scenarios there is significantly more peak supply potential than peak demand.

Chapter five

[24] As of 1st June 2015, Avonmouth storage site to close on 30th April 2016.

Gas supply

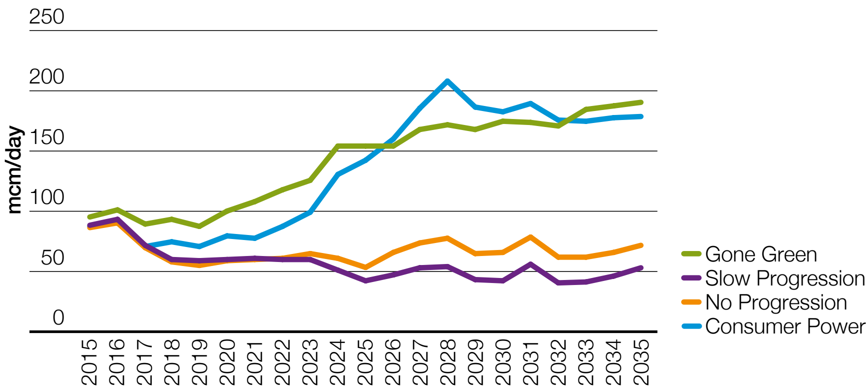
Figure 80
Peak gas supply in 2035



To ensure there is sufficient peak supply to meet demand we carry out the N-1 test as implemented by the European Commission. This assesses whether there is sufficient supply to meet demand when the largest single piece of infrastructure is removed. For all scenarios this represents losing supply from both LNG terminals at Milford Haven, a loss of 86mcm/day.

Figure 81 shows the margin by which supply exceeds demand, with the N-1 condition applied, and shows that all of our scenarios pass this test. In **Gone Green** and **Consumer Power** the margins grow from today. This is driven by the high peak supplies in **Consumer Power**, and the falling peak demands in **Gone Green**. In contrast, margins fall in **Slow Progression** and **No Progression** but remain greater than 40mcm/day.

Figure 81
N-1 margins



As all scenarios maintain a margin under the N-1 test, no additional capacity has been added in any of the scenarios, consistent with the gas rule described in section 3.1.3. We do not discount new import and storage projects being developed. We have seen projects developed for a variety of reasons such as to diversify a supply portfolio, to allow producers access to the optimum market or to support the power generation market in scenarios dominated by intermittent low carbon generation.

Gas supply

Method

Annual supply match
Indigenous gas production (UKCS/Shale/Biomethane) is driven by the primary assumptions and is allocated first. The minimum levels of LNG and continent are then applied along with Norwegian imports, which are determined by the conditions of the scenario. A match is then achieved by applying generic imports.

Locational supplies
The FES scenarios form the basis for our locational supply analysis; this is detailed further in the Gas Ten Year Statement (GTYS) and is the basis of our network analysis.

5.3.10
Scenario disruptors

In response to stakeholder feedback we have considered two potential disruptors to the scenarios. While the primary assumptions define many of the key variables which impact gas supply, there remain considerable market and physical uncertainties which have the potential to impact the supply mix across all scenarios.

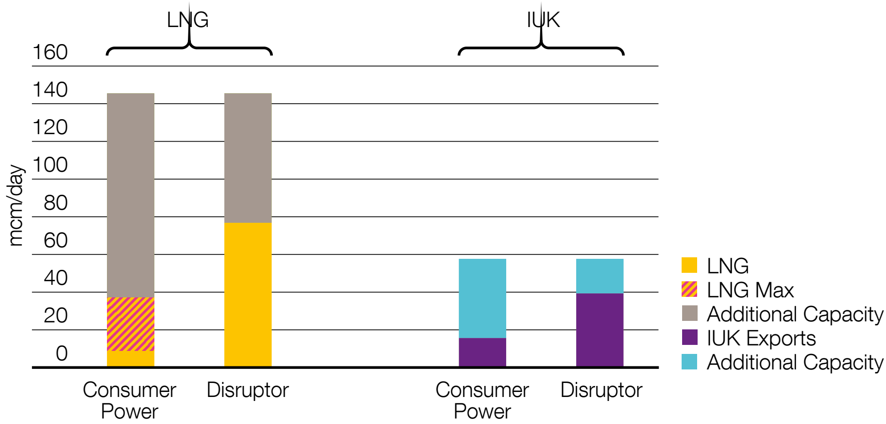
For both disruptors we have looked at the impact on the **Consumer Power** scenario. The effect of the disruptors is greatest in this scenario; however, the other scenarios could also be affected.

Disruptor 1 – transit GB
In this disruptor we assess the impact of GB becoming a transit hub to supply LNG to continental Europe.

With high levels of LNG available to European markets, LNG increases its market share as it becomes cheaper than developing other sources of imports. To enable the LNG to be utilised in both northern and central Europe the existing terminals in the Netherlands, Belgium and GB are used to land the gas which is then re-exported along existing export routes.

For GB this sees much higher utilisation of the LNG terminals, along with higher exports via IUK compared to **Consumer Power**. This grows throughout the duration of the scenario and is greatest in 2035, as can be seen in Figure 82.

Figure 82
2035 utilisation of IUK and LNG



Disruptor 2 – low indigenous production

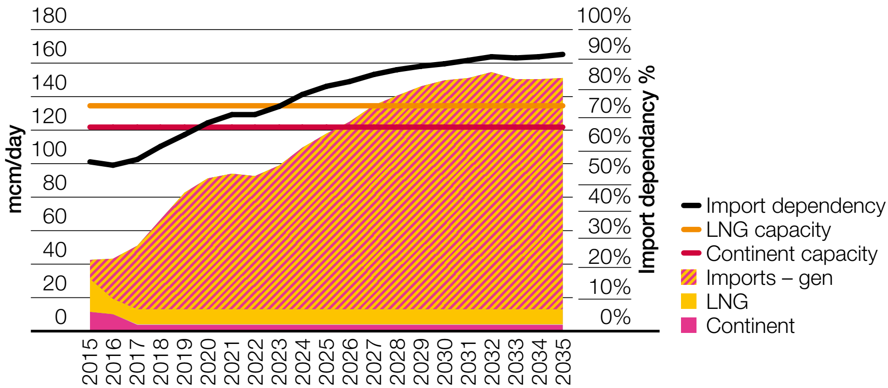
In this disruptor we assess the impact of lower production from both the UKCS and shale gas in the **Consumer Power** scenario.

There are no changes to the primary assumptions for this disruptor; the favourable conditions for high domestic production remain, as do those driving higher gas demands than our other scenarios. However, there remain significant uncertainties which are not driven by the primary assumptions; the overall level of reserves, the complexity of the reservoirs they are held in and the available technology to produce the gas. In addition to these there are several barriers required to realise the high levels of shale production as described in section 5.3.3.

To assess the impact of these uncertainties we have applied our low case for UKCS production from the **Slow Progression** scenario. For shale gas we have applied the zero case used in both **Gone Green** and **Slow Progression**. This results in a significantly higher import requirement than in **Consumer Power** without the disruptor, as can be seen in Figure 83.

Gas supply

Figure 83
Generic imports



While the import dependency, at around 90%, is similar to that in **Slow Progression**, the volume of imports is far greater. The existing sites would no longer have sufficient capability for all of these generic imports to be made up of either LNG or continental imports.

In order for the UK to ensure reliable imports at the levels required, the appropriate investment signals would need to be sent to upstream producers to ensure actions are taken to supply the GB market. These could be in the form of long-term contracts, as is typical in both Japan and much of Europe, or strategic partnerships with producers similar to the South Hook project.

It is also possible this could drive expansions to either continental import pipelines or LNG terminals. And while overall there is enough current capacity to supply the required gas, global market conditions could result in price differentials between imports from the continent and LNG. If these differentials are significant they could provide the signals to develop expansion projects to enable access to the cheaper source of gas.

Chapter six

2050 and environmental targets

2050 and environmental targets

6.1
2050 and environmental target progress

Renewable electricity, mainly from wind, contributes most to reaching the 2020 renewables target. To progress towards the 2050 target, low carbon electricity is needed to underpin the electrification of heat and transport. In Gone Green, heat pumps become the largest provider of heat in 2050, but there is still an essential role for gas to provide top-up heat. Without gas, meeting peak heating demand would be considerably more expensive, as power stations and networks would be built and used infrequently.

Gone Green is the only scenario which achieves all of the environmental targets on time. The other scenarios miss them by varying degrees.

Key statistics

- To achieve our 2050 carbon target in **Gone Green** almost all electricity is decarbonised by 2040.
- In all scenarios, electricity generation carbon intensity approximately halves by 2020, due to a combined reduction in coal generation and increase in renewable generation.

2020

In all scenarios, electricity generation carbon intensity approximately halves by 2020, due to a combined reduction in coal generation and increase in renewable generation.

This section describes the outcome of our 2050 modelling and analysis of our scenarios against environmental targets.

The FES scenarios are evaluated on a granular basis up to 2035. Beyond this date they are extended out to 2050 using a longer term modelling technique. A separate, whole energy system model is required to assess performance of energy scenarios against renewable and carbon targets.

For the 2050 analysis, an optimisation model is used which swaps energy demands (heat, transport and electricity) between energy sources. It is constrained to align with our pre-2035 analysis in every aspect possible. Due to the different nature of the two modelling techniques, some minor discrepancies are unavoidable.

This section describes progress against targets for our scenarios. As our **Gone Green** scenario is the only one to achieve all the environmental targets on time, this section discusses **Gone Green** in more detail. Other scenarios are described for comparison in the section. Full details of all scenarios are in our associated data workbook publication.

Environmental targets

There are currently two relevant environmental targets that we consider for our scenarios. 2050 greenhouse gas target – This target is to reduce annual UK emissions of carbon dioxide and carbon dioxide equivalent gases by 80% from 1990 levels in 2050. We have assumed progress towards this in line with UK carbon budgets.

2020 renewables target – The 2009 Renewable Energy Directive (RED) set a target for the UK to achieve 15% of its energy consumption from renewable sources by 2020.

There is currently no renewables target beyond 2020 but the EU is currently working towards reaching agreement on new targets for 2030. Therefore, we have extended the renewables target out to 2030 based on the Green Alliance analysis of a potential UK 2030 renewable energy target. A linear extrapolation of this target from 2020 has been used to generate a 2050 renewables target. The renewables target for the UK in 2020 is 15%. We use 23% and 39% for 2030 and 2050 respectively.

Figure 84
Environmental targets used in scenarios

Consumer Power

Environmental targets are missed, and no new environmental targets introduced.

2050 greenhouse gas reduction target: on target until around 2030 when progress stalls, ultimately missing 2050 target

2020 renewables target: missed

No new renewables targets for 2030 and 2050 are introduced

Gone Green

All environmental targets are achieved, including assumed new European targets post-2020.

2050 greenhouse gas reduction target: hit

2020 renewables target: hit

Assumed 2030 renewables target: hit

Assumed 2050 renewables target: hit

No Progression

Environmental targets are missed, and no new environmental targets introduced.

2050 greenhouse gas reduction target: missed and progress stalls

2020 renewables target: missed

No new renewables targets for 2030 and 2050 are introduced

Slow Progression

All environmental targets missed but achieved later. New European targets post-2020 introduced.

2050 greenhouse gas reduction target: missed but achieved later

2020 renewables target: missed but achieved later

Assumed 2030 renewables target: missed but achieved later

Assumed 2050 renewables target: missed but achieved later

Chapter six

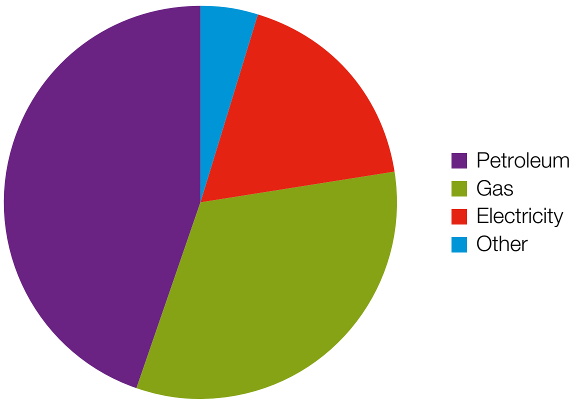
2050 and environmental targets

Gone Green achieves all environmental targets on time due to high green ambition in a high prosperity economy. **Slow Progression** achieves the targets but at a later date, generally achieving around 80% of the target on time and projected to reach the 2050 carbon target around 10-15 years late. **Consumer Power** misses the 2050 carbon target by our design, but in 2030 its trajectory is still on a pathway that could achieve 2050 target if environmental ambition increases. **No Progression** misses all environmental targets due to the lack of green ambition and low prosperity.

Energy background
UK energy demand is divided into three primary sectors: heat, transport and electricity.

Figure 85 shows the breakdown of end user demand by fuel type in 2013. The total annual demand is 1,746TWh. Conventionally, petroleum is mainly used for transport, gas mainly for heat and electricity for power. However, there is interchangeability between these fuels for their end use, which becomes the key to achieving environmental targets. The category 'other' includes coal, manufactured fuels, renewables, waste, and heat sold.

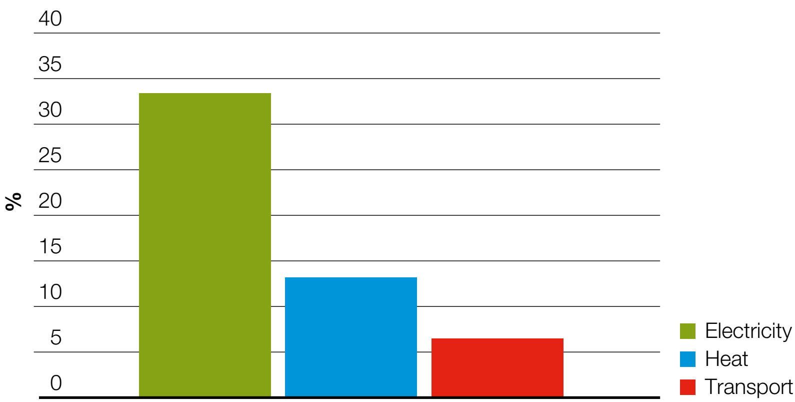
Figure 85
Final energy consumption by fuel, 2013



Whilst most progress towards environmental targets occurs in the electricity generation sector, improvements are also made in the heat and transport sectors. This is because, in comparison with other sectors, it is relatively less difficult to decarbonise electricity supply by utilising low carbon and renewable generation sources. Once this supply has been decarbonised, low carbon electricity can be utilised in the transport and heating sectors, to begin decarbonising these sectors too.

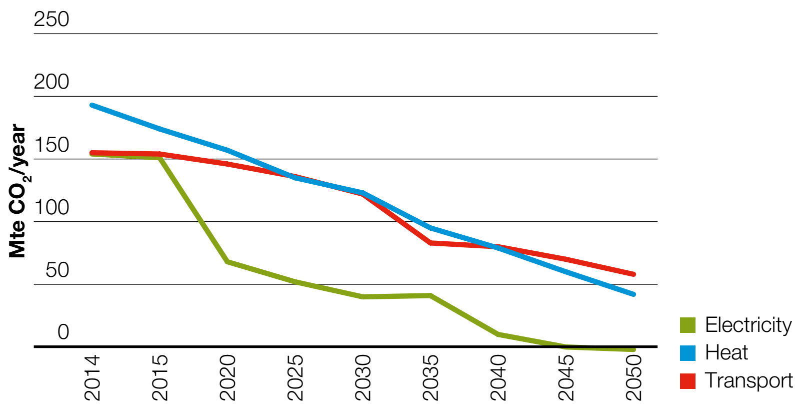
In 2020, in our **Gone Green** scenario, around 33% of electricity generation is renewable. Around 13% of heat demand is met from renewable sources and around 7% of transport fuel is renewable. This equates to electricity generation contributing around 110TWh/year, while heat and transport contribute around 90 and 40TWh/year respectively.

Figure 86
Gone Green: *2020 renewable percentage of energy supply*



By 2050, in our **Gone Green** scenario, electricity produces almost zero emissions, falling steadily from 60Mte CO_2 per year in 2020. Heat and transport emissions fall across the same period, both reaching approximately 50Mte CO_2 per year by 2050.

Figure 87
Gone Green: *emissions from each sector*



Chapter six

2050 and environmental targets

Energy scenarios
This section details how our **Gone Green** scenario reaches the 2050 carbon target. It shows details of **Gone Green** with the other scenarios for comparison. The full detail for all scenarios is available in the associated FES data workbook publication.

To achieve the 2050 targets, **Gone Green**:
1. Decarbonises electricity generation, then
2. Increases decarbonised electricity supply.
3. Electrifies large quantities of heat and transport and uses decarbonised electricity to power this.
4. Explores other options for heating and transport such as hydrogen.

The subsequent gas demands are the result of the remaining heat, power and transport requirements.

The detail of this is illustrated in this order in the subsequent sections.

6.1.1 Power supply

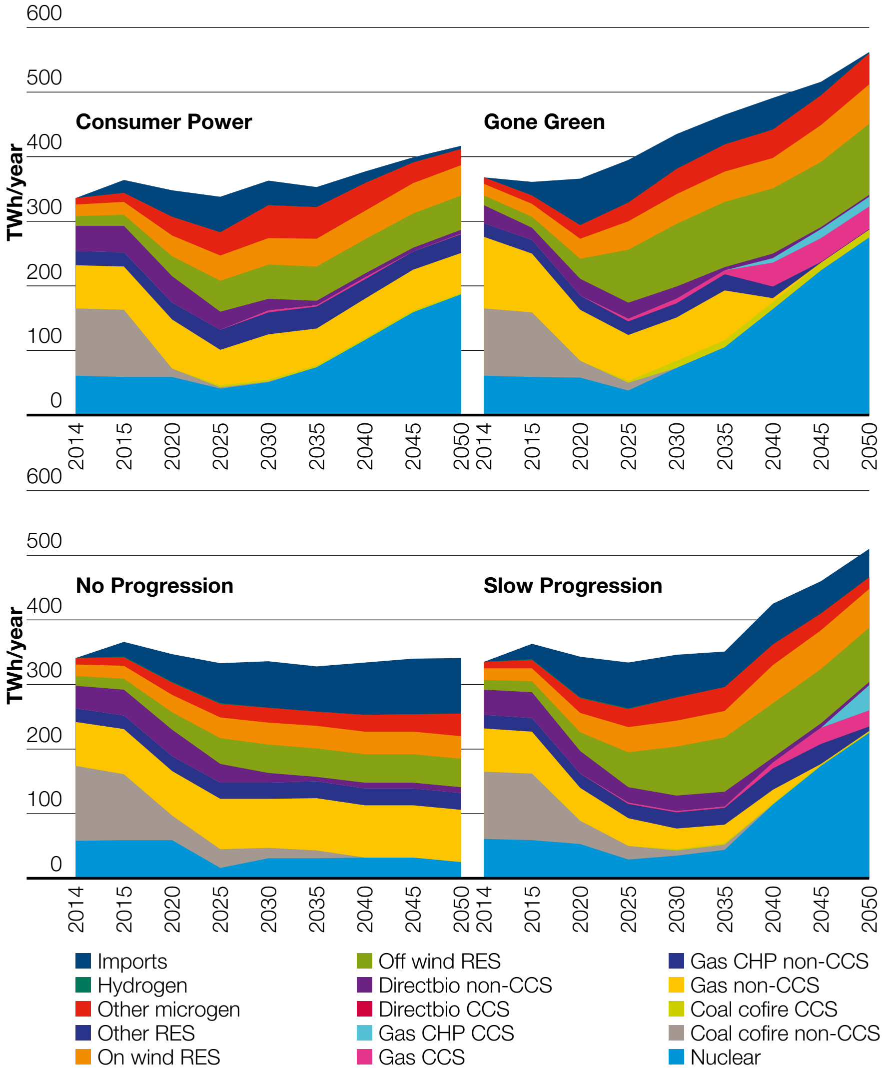
In **Gone Green**, annual renewable electricity supply increases up to 2030 mainly from wind power, with a lesser contribution from other renewables. This offsets a decline in electricity generation from gas and the complete decommissioning of unabated coal based generation. Interconnection forms a considerable part of GB gross supply due to the renewable generation mix. Whilst solar PV has a large capacity and impact at its peak output, it has relatively little contribution to annual supply due to its low annual load factor of approximately 10%. Further into the period, from around 2030, CCS and nuclear generation increases, increasing supply from low carbon sources. The culmination of these factors results in the electricity system being almost fully decarbonised by 2050. This occurs concurrently with electricity supply rising to meet the demand for the electrification of heat and transport, aiding the decarbonisation of these sectors.

Slow Progression has similar supply changes but with less renewables, more gas and less low carbon growth beyond 2030. Overall supply is lower than in **Gone Green** in 2050 as less heat and transport is electrified. The slower changes in the generation mix, along with the slower electrification of heat and transport mean that environmental targets are met after the 2050 deadline.

Consumer Power and **No Progression** have little ambition to achieve environmental targets after 2020 hence the cheapest form of electricity generation is chosen. Additionally, the prosperity in our **Consumer Power** scenario facilitates investment in embedded renewables, particularly solar. This also enables later capital investment in nuclear power, as this is seen as the longer term cost efficient option. Less affluence leads to a greater reliance on gas and imports in our **No Progression** scenario.

Consumer Power is a high embedded scenario characterised by high solar, with 31GW installed by 2035.

Figure 88
Annual power generation by supply type to 2050



2050 and environmental targets

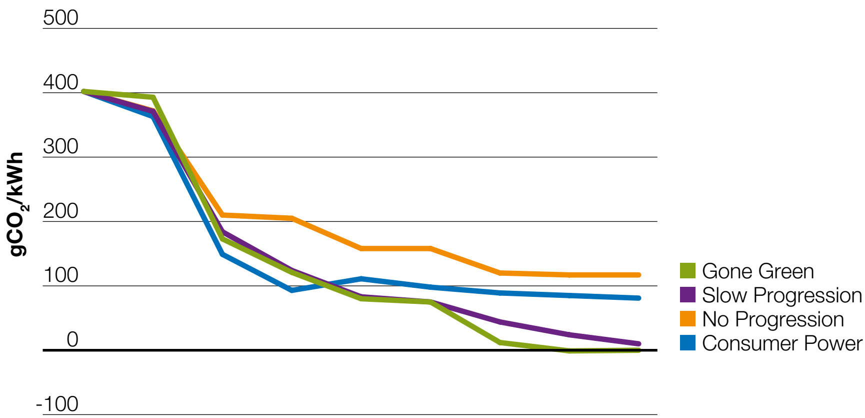
The carbon intensity of power generation decreases considerably in all scenarios to relatively similar extents up to 2020. This is because we have relatively high confidence in changes to power supply over the next few years. The most important of these changes is the reduction of coal fired power generation combined with varying degrees of increasing renewables.

In the medium term all scenarios except **No Progression** continue to decarbonise at similar rates. Our **Consumer Power** scenario is close to both **Gone Green** and **Slow Progression** as it has high renewables from embedded generation (notably high solar).

This shows that in 2030 **Consumer Power** is still on a pathway that could achieve later carbon targets. The lower renewable ambition has greater impact from this point, leading to limited further progress.

In 2050 the carbon intensity of electricity generation is lowest in **Gone Green** and **Slow Progression**, with **Gone Green** reaching zero emissions earlier. **No Progression** experiences the least change from today's level, but still falls by around two thirds by 2050. The minimal fall in emissions in **Consumer Power** beyond 2030 is mostly due to increases in nuclear generation.

Figure 89
Power: CO_2 intensity



All scenarios have reductions in coal generation, combined with increases in renewable generation. This results in carbon intensity of electricity generation roughly halving by 2020.

6.1.2
Power demand

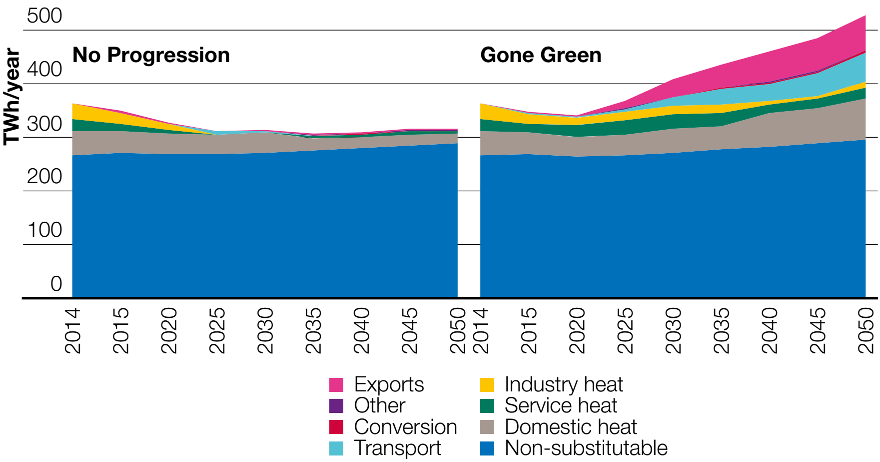
In **Gone Green**, the decarbonisation of electricity generation and increases in low carbon supply facilitate electrification of heat and transport. This consequently starts to decarbonise these sectors. High renewable generation creates a greater need for energy balancing due to the inherent variability of supply. Increased interconnector capacities help facilitate this. Excess generation is exported via the interconnectors. In stark contrast to this, **No Progression** has few drivers to decarbonise, causing total demand to be much lower. The lack of excess generation from renewables causes exports to be much lower.

Slow Progression follows similar trends to **Gone Green** but has fewer increases in electricity demand for transport and heating as there is less low carbon generation supply. Gross exports are smaller due to less excess generation being available.

Consumer Power has similar demands to **No Progression**, but higher overall generation means some electricity can be used for transport and some is exported.

Demand in **Gone Green** is nearly 50% higher in 2050 than today's levels; driven largely by demand from heat pumps and electric vehicles.

Figure 90
*Power demand: **No Progression** and **Gone Green***

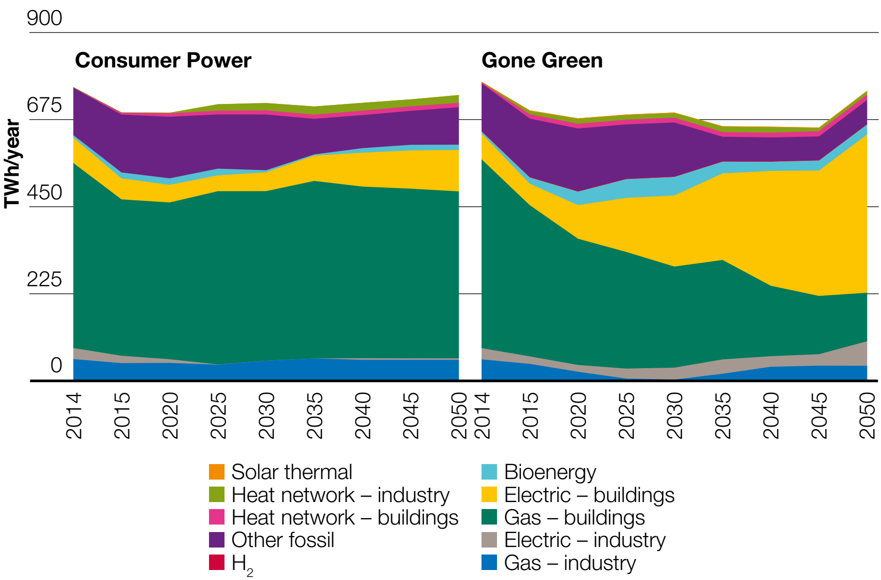


2050 and environmental targets

6.1.3
Heat demand

In **Gone Green**, high levels of low carbon generation enables heat to become electrified and there is a significant drive from both the government and energy users to alter demand patterns. In **Consumer Power**, the lack of drive towards environmental targets means little heat is electrified, with gas appliances continuing to dominate the market. This shows the two extremes for heat demand in our scenarios. Our **No Progression** scenario is very similar to **Consumer Power**, as they share a lack of green ambition. **Slow Progression** has similar yet slower trends to **Gone Green** as there is less advancement towards the carbon targets.

Figure 91
*Heat demand: **Consumer Power** and **Gone Green***



6.1.4
Transport demand

All our scenarios assume the same overall numbers of vehicles and transport miles. The differences between scenarios for energy demands arise entirely due to the inherent efficiencies of different fuels used.

In **Gone Green**, high levels of low carbon generation enables transport to become electrified, which helps to decarbonise the sector. Significant electrification of cars occurs, with just over 90% of cars on the GB roads being electric in 2050. This is split evenly between pure EVs and plug in hybrids in 2050. As electric vehicles are approximately three times more efficient than internal combustion engines, total demand for transport decreases. Additionally, gas and hydrogen become the main fuels for HGVs after 2030. Gas use is partially due to its renewable benefits but mainly due to cost credentials. Hydrogen is utilised heavily in this sector mainly due to the renewable credentials that arise from how it is created, and the fact that HGVs are less suitable for electrification. It is assumed to be used in fuel cells in HGVs. In our assumptions, hydrogen is produced from gasification of biomass (with CCS), further helping decarbonise the transport sector. Some steam methane reformation of natural gas is also employed to generate hydrogen from 2045.

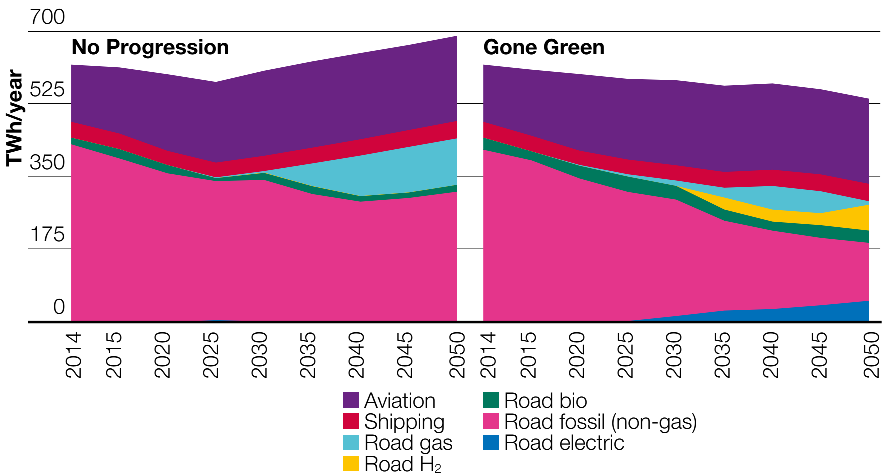
The contrasting scenario to **Gone Green** is **No Progression**. In this scenario there is minimal electrification of transport and no further development of hydrogen technology. There is still a move to change fuel use of HGVs to gas as it is the most cost efficient option on a long-term basis. Whilst efficiency improvements in conventional transport are accounted for, greater efficiencies of electrification are not realised. As a result, transport demand increases as do carbon emissions from the sector.

Our **Consumer Power** scenario has very similar trends to **No Progression** for the same reasons. The difference between these scenarios is due to electric vehicles, which are relatively high in **Consumer Power**. This reduces overall transport demand due to their increase efficiency.

Slow Progression follows similar trends to **Gone Green** but the reduced performance against environmental targets means much less hydrogen is used for HGVs from 2030, with the remaining using natural gas.

2050 and environmental targets

Figure 92
*Transport demand: **No Progression** and **Gone Green***



6.1.5
Gas demand

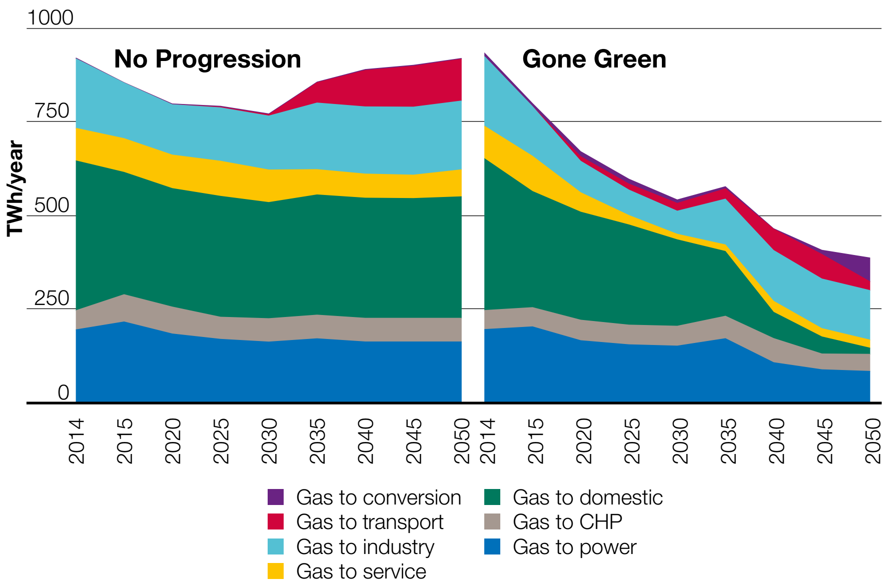
In **Gone Green**, gas demand reduces to around half today's level in 2050, mainly due to the annual reduction in gas for heating in domestic and commercial applications. Gas is still heavily relied on for cold weather periods for top-up heating in these sectors, as a large proportion of domestic and commercial heating systems are hybrid gas/electric systems. This is detailed in Figure 93. The high temperatures of industrial applications mean this sector is difficult to electrify, so industrial gas demand remains relatively unchanged. Gas used for power generation falls, and almost all remaining gas CCGTs use CCS (with or without CHP). Some additional gas is used beyond 2030 for HGVs and later for hydrogen production.

Again the contrasting scenario is **No Progression**, where gas boilers dominate the residential heating market and CCGT demand remains high without CCS. This results in total annual gas demands that are similar in 2050 to today's levels.

Our **Consumer Power** scenario has very similar gas demand to **No Progression**, as demand from heat, transport and power stations are alike. **Slow Progression** again has a similar but slower trend in gas demand to **Gone Green** due to the reduced performance against environmental targets.

With very high electrification of heat, significant gas is still required for top-up in times of cold weather to keep costs down, otherwise significant power generation capacity will need to be built to manage extra peak electricity demand.

Figure 93
*Gas demand: **No Progression** and **Gone Green***



2050 and environmental targets

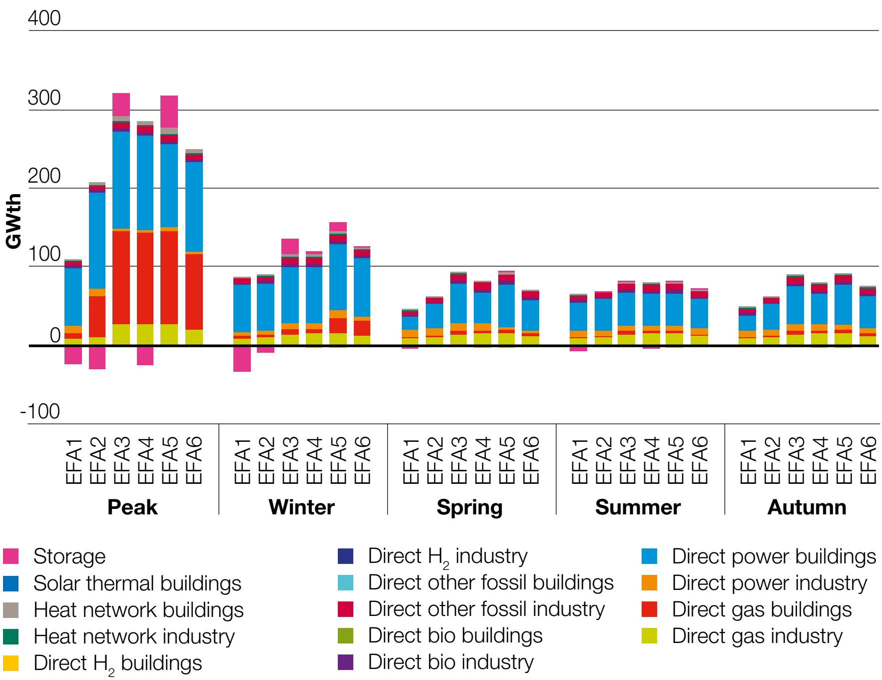
The optimal way of heating GB across seasons and at peak times has been analysed. This is illustrated in Figure 94 with the seasonal heat requirements from the **Gone Green** scenario in 2050. Demand for heat has a large seasonal and within-day variation, much more so than electricity.

By 2050, electric heat pumps are used to supply the majority of the heat load, but to electrify the entire load would require significant investment in generation and electricity network capacity.

Figure 94 illustrates how heat is supplied over a peak day and an average day for each season.

Each Electricity Forward Agreement (EFA – 4 hourly time periods into which an electricity day is split) timescale represents 4 hours of the day (EFA1 is 23:00–03:00hrs, EFA2 is 03:00–07:00hrs, etc). This chart shows that whilst the majority of heat is met by non gas heating in warmer periods, on colder days and at peak a significant amount of gas is required for heating. The same conclusion occurs when looking at **Slow Progression** in 2050, hence hybrid systems are included in both these scenarios. **No Progression** and **Consumer Power** need gas for heating all year around, as this scenario has little electrification of heating in 2050.

Figure 94
***Gone Green:** heat duration supply curve for 2050*



Chapter six

6.1.6
Areas for further investigation

The 2050 modelling highlights some requirements which are necessary in order to meet the 2050 targets. To meet the targets electricity generation needs to be almost fully decarbonised by 2050. Additionally, this decarbonised electricity generation will be used to meet increased demand from heating and transport. Increased decarbonised electricity generation requires extra flexibility which increased interconnection can aid via diversification of supply and demand.

There are other areas which are less clear past 2030. For example it is unclear how much bioenergy can be used and whether it is used to meet heating demand or for hydrogen fuel. There is also a question as to how the electricity system is balanced; what the role will be for DSR, TOUTs, smart appliances and electricity storage. The role and use of hydrogen is also less prescribed; whether it be for HGV transport (as it is in our scenarios) or for energy balancing. We have engaged with our stakeholders to ensure the amount of hydrogen produced in our scenarios is aligned with industry perspectives.

Heat networks can have a role to play in the future, and do feature in our scenarios. Uncertainties exist around the potential size of heat networks, costs, potential carbon implications and who the customers are likely to be. Our Future of Heat case study in chapter 7 elaborates on our current thoughts.

National Grid is committed to build knowledge in these areas to improve our whole energy system modelling. We aim to do this through our FES process and further engagement. We will be holding workshops to establish exactly what is known and what is less so, and what options exist in the areas of high uncertainty. These workshops are currently planned for autumn 2015. They are intended to be the precursor to a wider 2050 document, analysing some of the pathways towards achieving 2050 carbon targets.

2050 and environmental targets

Method

We use a cost optimisation model for our 2050 and target analysis, which was developed by Baringa. This model is known as RESOM (Redpoint Energy Systems Optimisation Model). RESOM is a whole energy model which selects the least cost solution which balances on a seasonal, annual and peak basis.

Approximately 5,000 constraints are used for each model run to produce a set of 2050 scenarios which align to our pre-2035 analysis.

The model inputs and constraints are evaluated against external benchmarks, including the ETI (Energy Technologies Institute).

We will build our knowledge of 2050 options via FES engagement and 2050 workshops.

Chapter seven

Case studies

Balancing

Future of heat

Security of supply

Green lights for electricity storage

Balancing

7.1
Power balancing challenges

Future summers will see periods of low transmission demands due to the increasing amounts of generation embedded within the distribution networks; in particular solar photovoltaic (PV). These increases, without action, will create balancing challenges for the system operator (SO). This case study considers these challenges for a typical summer Sunday in 2020, using the Consumer Power scenario.

The analysis shows that with average solar output, transmission demand is being suppressed across a large part of the day, dropping to a minimum of 16.7 GW in 2020. There will still be a need to hold generation at part load to cater for unforeseen events on the system. Therefore total generation is likely to exceed demand.

Key statistics

- Minimum demand falls to 16.7 GW in July 2020 in **Consumer Power**
- Under high solar outputs, demand remains flat across the day
- Operability and balancing challenges impact all scenarios at different points in the future.

16.7 GW

Minimum demand falls to 16.7 GW in July 2020 in **Consumer Power**

Innovative solutions are likely to be required to address these challenges. For example, greater flexibility from existing sources of generation and demand, greater use of interconnection, more demand side response or the development of energy storage and new balancing products. National Grid's System Operability Framework (which is published in autumn each year) will be the process where we work with the industry to explore operability challenges and identify potential solutions.

Fact

- 11 August 2014, minimum demand fell to 19 GW, which led to 13 consecutive ½ hour periods of negative generation prices.

19 GW

11 August 2014, minimum demand fell to 19 GW, which led to 13 consecutive ½ hour periods of negative generation prices.

7.1.1 Introduction

Last year our stakeholders asked us to consider energy balancing in our scenarios and to consider the impacts and challenges from changing supply and demand patterns.

As SO, we must match demand for electricity with supply on a second-by-second basis. Historically, balancing the system has been maintained mostly by directing thermal power plants to increase or reduce output in line with changes in demand. Storage and interconnectors have also played a part, but a much smaller one. As the volume of intermittent generation on the system grows, we will balance the system by utilising both supply and demand resources.

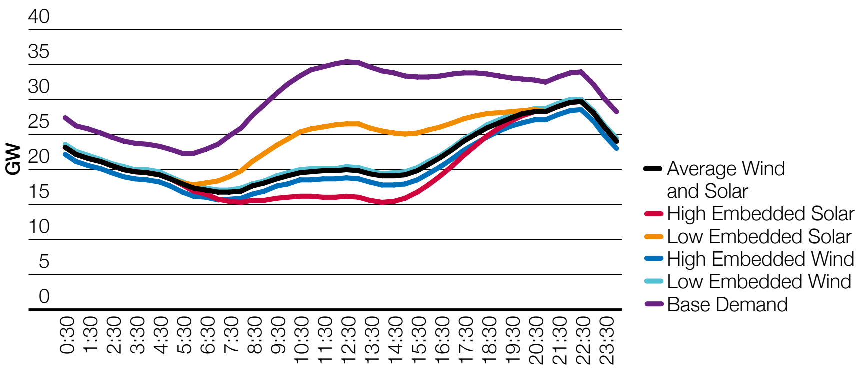
Managing periods of low electricity demand in the summer is just as important as managing the high demands we see in the winter. We have undertaken analysis to look at a typical summer Sunday with low demand using the **Consumer Power** scenario (due to its large volumes of intermittent distributed and micro generation).

Balancing

7.1.2
Distributed and micro generation impact on summer transmission demand

There is a direct correlation between the volumes of distributed and micro generation and low transmission demand. Historically, summer minimum demand was at 06:00hrs. This was reflected within the base demand value (which excludes distributed and micro generation) shown in Figure 95. However, as the amount of distributed and micro output increases on the system, this minimum demand shifts to 07:00hrs. The demand profile is also flattened as distributed and micro generation offsets the transmission demand.

Figure 95
2020 Summer transmission demand profiles for Consumer Power



7.1.3
Impacts of solar PV

The technology that has the single most significant impact on transmission demand is distributed and micro solar PV which is illustrated by the red line in Figure 95. Transmission demand is supressed to 15 GW by 07:00hrs. This level of demand is maintained to 14:00hrs as increasing solar output offsets transmission demand. Between 14:00hrs and 20:00hrs transmission demand climbs as output from distributed and micro solar PV reduces.

Solar capacity has already had a rapid rise from 0.9 GW in 2011 to 5.2 GW in 2014. This rate is expected to increase to reach an installed capacity of 18 GW in 2020.

We have considered three load factor sensitivities for solar output at 14:00hrs: high (84%), average (63%) and low (26%). The difference in transmission demand between high and low output could be a swing of up to 10 GW. Focusing only on average solar conditions during July, demand is supressed to a minimum of 16.7 GW (at 07:00hrs).

7.1.4
Is this just an issue for Consumer Power?

Whilst the case study focuses on **Consumer Power** (due to its high distributed and micro generation capacity levels) we have analysed the opposite scenario **Slow Progression**. We explored the summer demand profiles for **Slow Progression** in five year intervals to discover when this scenario would face the same challenges as **Consumer Power**.

> **Slow Progression** has slow economic growth and high emphasis on sustainability; the opposite environment of **Consumer Power**.

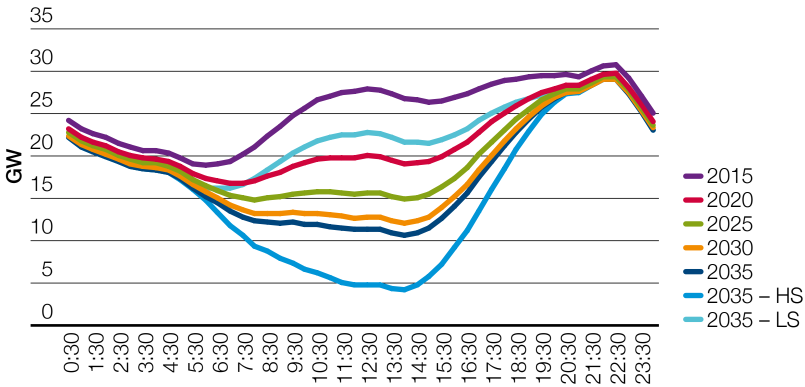
Analysis shows that by 2035 afternoon minimum demands are at similar levels to **Consumer Power** in 2020. This highlights that across all four scenarios we will experience balancing and operability challenges at some point from 2020 onwards.

In continuation we explored **Consumer Power** over the same period. In Figure 96 we can see that by 2035 the pattern of transmission demand has significantly changed. There is no longer any increase in transmission demand in the first half of the day as it falls continually from midnight until 14:00. This produces a steeper ramp rate in evening demand which is very pronounced by 2035 under **Consumer Power**; producing a 16 GW rise in 6 hours.

Figure 96 shows the demands under both high (HS) and low solar (LS) output conditions for 2035 for **Consumer Power** are highlighted, showing that transmission demand could swing by 17 GW within-day solely due to a change in cloud cover.

Balancing

Figure 96
Consumer Power summer transmission demand across years



7.1.5
Balancing and cash-out

Balancing the system during low transmission demand periods is a challenge. At all times there must be sufficient generation plant operating to allow output to decrease without any generator going below its minimum output level and disconnecting from the system in case of demand forecast error or loss of demand on the system; this is known as foot room. At the same time, there must be sufficient generation part loaded, ready to pick up for a generation loss; known as headroom.

Low transmission demand can also have an effect on cash-out pricing. On Monday 11 August 2014 minimum transmission demand was 19 GW and led to 13 consecutive ½ hour periods of negative generation prices (settlement periods 01:00 to 07:30), as we constrained excess wind generation off the system.

Historically in low demand periods we have constrained generation and interconnector imports to maintain system security. With a growing proportion of summer generation coming from distributed and micro generation, especially from uncontrolled intermittent sources such as solar and wind, the balancing challenges are likely to increase.

7.1.6
The way forward

To address the balancing challenge we need to undertake further analysis and work alongside the industry to develop solutions. These solutions may include the provision of greater flexibility from existing sources of generation and demand. This could be achieved if such resources had the capabilities to start and stop multiple times per day and start up with short notice from a zero or low electricity operating level.

Greater use of interconnection may also play a part, mindful of the fact that the ability to export power depends on the needs of neighbouring countries. The development of energy storage, new balancing products and services, greater visibility and/or control of all generation or even a more fundamental reform could also form part of the solution.

Some of these issues are already being considered via various projects within the industry and we wish to use this information to develop our analysis. National Grid's System Operability Framework will address the operability issues in detail later this year. Going forward we would welcome your views on this case study and suggestions for further development for next year's analysis.

Although in its infancy, demand side response is already a reality.

power responsive

The ability for businesses and consumers to increase, decrease or shift their pattern of electricity consumption allows them the opportunity to save on energy costs, reduce their carbon footprint and help address these balancing challenges. Power Responsive is an ongoing framework to facilitate demand side response.

Find out more at www.powerresponsive.com and join the debate on LinkedIn

Balancing

Method

An average Sunday demand profile for July is derived from the data for 2005-2008/09. The base demand profile does not include distributed and micro generation impacts. This profile is then scaled against the summer minimum demand values for 06:00hrs for the appropriate scenario and year; again excluding any distributed and micro generation effects to produce a base demand daily profile.

We used distributed and micro generation capacity by technology type and exclude distributed and micro solar and wind which were dealt with separately. These capacities are specific to the appropriate scenario and year which is then profiled over the day based upon the 06:00hrs and 14:00hrs summer generation load factors. For example distributed combined cycle gas turbine (CCGT) was profiled to a 06:00hrs value of 26% and a 14:00hrs value of 40.5%.

We used average July daily load profiles for both wind and solar generation. These were used to scale the distributed and micro solar and wind capacities. For the sensitivities for both solar and wind the daily load profile was scaled from the average. For example the average solar was scaled from a 62% load at 14:00hrs to the 84% power supply summer 14:00hrs load factor.

The resultant distributed and micro generation was removed from the base demand to produce a transmission demand profile; including sensitivities for high and low solar and wind.

We utilised the quarterly (summer quarter) power supply output values for the **Consumer Power** scenario. These were converted into average generation outputs for the settlement period.

Future of heat

7.2
Future of heat

Energy used in heating demand is currently very carbon intensive and accounts for a significant proportion of GB's carbon emissions. If the carbon targets are to be met, there must be a step change in how our homes and businesses are heated. There are many solutions coming to market that aim to facilitate this change. We see a need for a combination of these solutions, with enabling technologies, to decarbonise heat at the most efficient cost to consumers and we see gas continuing to have a key role.

Key statistics

- Almost half (46%) of the final energy consumed in GB is used to provide heat, around 700TWh/year
- Around 80% of heat demand is currently met with natural gas
- Heat is responsible for around a third of GB's greenhouse gas emissions.[6]

[6] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48574/4805-future-heating-strategic-framework.pdf

Chapter seven

Future of heat

7.2.1
Why is heat a problem?

Heating buildings accounts for around 700TWh/year of energy demand in GB, around half of the total demand. Most of the energy demand is for domestic space heating and is satisfied with natural gas boilers in homes throughout the country. However, residential and industrial sectors are responsible for roughly equal emissions due to industry needing higher temperature heat, which is provided by more carbon-intensive fuels. Space heating resulted in the emission of approximately 100 mega-tonnes of carbon dioxide equivalent ($MtCO_2e$) into the atmosphere in 2008, 18% of the total carbon emissions including industry, power stations and transport. Total heat demand, including industry, contributed 182 $MtCO_2e$, bringing the total to 32%.

To meet the government's legally binding carbon targets (80% reduction in carbon emissions against 1990 level by 2050), the energy used in heating must be decarbonised by reducing the amount used and focusing on using cleaner sources. The industry is starting to address this via a range of potential solutions.

7.2.2
Potential solutions

Heat pumps

The first place to start with reducing the carbon intensity of heat is to consider alternatives to traditional gas boilers. Gas boilers convert gas to thermal energy with an efficiency factor of approximately 90% before distributing the heat around buildings with a wet system (water in radiators) or a dry one (hot air in vents).

Replacing gas boilers with a different appliance, such as a heat pump, could be an effective solution. Heat pumps are designed to be far more efficient, taking advantage of the latent heat that exists in the air, the ground or in bodies of water. This means that there is potential to get two or three units of thermal energy for every one unit of electrical energy. Therefore, heat pumps have no carbon emissions at the point of use and also use less energy for the same thermal output: a win-win.

Heat pumps don't provide a perfect solution though as the implications of installing heat pumps across the country are significant. The cost of electrifying heating is significant, ranging from the network costs to more generation assets. These costs are passed on to the consumer through higher electricity prices. Heat pumps are also more expensive to install than gas boilers and need different heat distribution systems in homes to gas boilers, adding to their cost.

Heat pumps can be used in hybrid systems, where gas is used to 'top up' and meet heat demands at peak when the heat pump is running at its lowest efficiency. This setup avoids requiring an electricity system built to meet peak demand and the high associated costs. Using gas at peak utilises assets that already exist; without gas, meeting peak demand would be considerably more expensive.

The electricity still has to be generated in a clean way to see any carbon benefits (the carbon intensity of electricity from the grid is currently around 400-450 gCO_2/kWh), which means either more renewable generation or carbon capture and storage (CCS) must be built to reduce carbon emissions from thermal generation.

Industrial and commercial heat pumps can take advantage of waste heat from other processes. Refrigerators and freezers vent heat as part of their cooling system and this heat can be recycled, using heat pumps, at high efficiency to effectively move heat from places that need to be cooled to places that need to be warmed. These solutions can be bespoke for a particular building but still use off-the-shelf equipment.

Future of heat

Heat networks

Heat networks centralise the task of changing primary energy into thermal energy and remove the need for each individual building to have a heating appliance. This can take advantage of thermal economies of scale before circulating the heat into buildings via insulated hot water pipes.

Installing a new heat network is costly and disruptive: new pipes must be laid in streets and residents must support the scheme. To maximise heat networks' success, everyone in the catchment area needs to sign up to spread the initial investment costs. This requires residents relinquishing control of their heating systems, a prominent cultural change. Heat networks are most efficient in high density areas, allowing for shorter pipework and more participants and thereby keeping costs as low as possible.

Many of these setup issues can be addressed by installing the heat network in a new housing estate. This avoids the cost of digging up roads, required in a retrofit, because the work can be integrated into the build, avoiding some costs, and new residents will have the heating already installed without needing to make a conscious decision to become greener. This, however, leaves the developer with a legacy problem of who will own, run and maintain the asset as well as hold any associated liability if it breaks down.

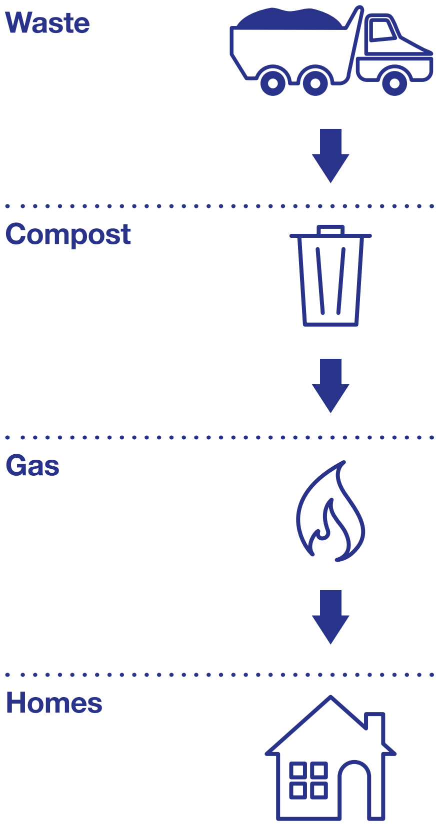
There are a range of possible heat sources, but the most effective would be to use waste heat from a power station or factory. This heat would usually be low grade (a lower temperature than required) but could be upgraded to a useful temperature and therefore make the heating appliances installed more efficient. This puts a second constraint on the location of an effective heat network: being close to a heat source.

Another option would be to use gas combined heat and power (CHP) units to generate both electricity and heat. The heat can be pushed through the network and the electricity exported to the grid or used to power heat pumps. This is greener than using grid electricity and a gas boiler in the short term, but there is a tipping point as grid electricity becomes greener (this depends on CHP efficiencies but it's around 1.4 times the intensity of burning gas) where CHP is then more carbon intensive than the alternative. Once the heat network is in place, the heating system can be transferred to alternative heat sources with minimal problems or CCS can be added.

Biogas
Biogas can be produced using a technique called anaerobic digestion (AD). This is where organic waste material is broken down by micro-organisms which expel biogas as a by-product. This gas can be cleaned up so that it is suitable to be injected into the local distribution network and then burnt to produce heat, just the same as natural gas. AD occurs naturally when waste is left to rot and the resulting methane is vented into the atmosphere. Biomethane has a double counting effect on reducing carbon emissions (not venting in the first place and replacing natural gas); this is because methane's impact on climate change is equivalent to about 25 times[2] the impact of CO_2.

Biomethane is chemically identical to naturally occurring methane and so can be used as an alternative, greener, source of gas. A significant benefit over other heating solutions is that biogas utilises the existing distribution networks and incumbent gas boilers.

However, a great deal of waste is required to produce biogas in serious quantities. One tonne of waste can produce anywhere from 100 to 3,000 kWh of biogas depending on the quality of the organic material.[3] It has been estimated that it is possible to produce and inject into the distribution network around 20TWh/year of biogas by 2050[4], although this represents less than 3% of the current gas demand. Given these restrictions biogas can only ever represent part of a wider solution.



[2] http://epa.gov/climatechange/ghgemissions/gases/ch4.html

[3] http://www.afbini.gov.uk/afbi-ad-hillsborough-27-months-june-11.pdf

[4] 4.25
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/190149/16_04-DECC-The_Future_of_Heating_Accessible-10.pdf

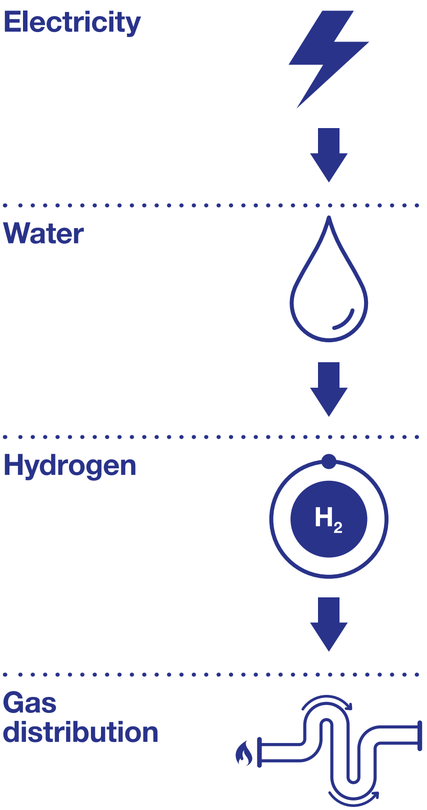
Future of heat

Hydrogen

Hydrogen is often proposed as a clean solution for energy. There are several issues which need addressing before this potential can be realised, ranging from production to transportation and end use.

The vast majority (more than 90%) of hydrogen production is currently done by chemical reactions with fossil fuels, primarily methane. However, this only moves emissions to a different point in the process. Alternatively, hydrogen can be produced with electrolysis and could take advantage of excess supply from renewables like wind and solar. The electricity is used to convert water into hydrogen and oxygen. Currently, however, this is not a very economic use of this spare capacity.

Once made, the hydrogen could be injected into the current gas distribution system in small quantities (up to 2% by volume[5]) which would effectively lower the carbon intensity of the gas from the grid. However issues need to be addressed with appliances being adapted to utilise hydrogen effectively. In larger quantities a hydrogen gas grid could be built along with hydrogen boilers installed in buildings; clearly a great deal of investment would be required to make this worthwhile and competitive.



[5] http://www.gerg.eu/public/uploads/files/publications/GERGpapers/HIPS_-_the_paper_-_FINAL.pdf

Next steps

Each of these solutions requires investment into technologies and infrastructure as well as gaining buy-in and acceptance from the end customers who will ultimately see a change in their home or business. There are physical constraints for some, like heat networks, which prevent wholesale installation. These technologies lend themselves to a mixture of installations, each targeted to resolve the problem of decarbonising heat in their own focus area.

For thermal generation to be decarbonised, and included in the heat mix, CCS will need to be part of the solution. CCS, a system whereby carbon emissions are captured at source and then piped back into the ground, is expensive to implement and needs infrastructure external to the power stations (or industrials) to function. Therefore they are most economical in high-density clusters of industrial activity and near a carbon sink point – the North East of England and Scotland are obvious contenders that meet both of these requirements.

To further investigate heat networks we have commissioned a study with Buro Happold and University College London (UCL), aiming to inform our scenarios for 2016. The study will review existing heat networks, the location and potential scale of economic heat networks and, crucially, the sources of low carbon heat production that could support a future heat network. We intend to also review the plausible expansion of CCS networks and interaction with potential heat and gas networks.

Understanding the practicalities, deployment and potential geographical opportunities for CCS and heat networks will have a knock-on impact to our energy demand and supply scenarios. We aspire to a better understanding of the interaction with existing and potentially new energy infrastructure, with a view of further enhancing our Future Energy Scenarios for next year.

None of these solutions are completely new, but they will require a step change to make them competitive against the current preferred heating solutions. The government may have a part to play in investment or incentives, as will obtaining economies of scale from interested parties working together in partnership to utilise waste heat efficiently. It is clear that a mix of solutions will be required that suits the infrastructure that already exists, is cost effective, and returns significant carbon reductions for the required investment.

Security of supply

7.3
Security of supply

This case study looks at the outlook for security of supply for the coming winter. Margins, whilst narrow, continue to be manageable until 2018/19 when the capacity market delivers new sources of capacity and margin pressures ease. The purpose of this section is to look at the immediate outlook for security of supply and describe the solutions that are in place to ensure adequate generation and Demand Side Response is available to meet the security of supply standard.

7.3.1
Introduction

Security of supply is concerned with how much generation is available to meet peak demand across a number of market outlooks. The aim of this case study is to consider security of supply for winter 2015/16 in detail and to share our thinking and analysis with the industry as part of work to increase transparency. Security of supply is a key area of focus as the generation mix diversifies over time; the level of traditional thermal generation decreases and the level of more intermittent renewable generation increases. This case study looks at the loss of load expectation (LOLE) in each of the scenarios for winter 2015/16 and sets out the actions taken in order to inform the market to support best planning.

LOLE is used to describe electricity security of supply. It is an approach based on probability and is measured in hours per year (hours/year). It measures the risk, across the whole winter, of demand exceeding supply under normal operation.

This does not mean there will be loss of supply for X hours/year. It gives an indication of the amount of time, across the whole winter, which the system operator (SO) will need to call on balancing tools such as voltage reduction, maximum generation or emergency assistance from interconnectors. In most cases, loss of load would be managed without significant impact on end consumers. The standard for Great Britain is set by the government at 3 hours/year LOLE. This assumes average conditions so the analysis considers a range of credible and plausible sensitivities to deliver security of supply across a range of outcomes.

For winter 2015/16 the SO has taken action by procuring new balancing services through a tender process. The tender process resulted in this additional generation being procured at a competitive price to deliver value for end consumers. This reduces the LOLE across the scenarios and these details are discussed later in the case study. Although the SO has taken action to improve the outlook for the coming winter, we believe the security of supply for winter 15/16 is manageable. We will continually review the latest position and remain vigilant regarding security of supply as we approach winter.

Security of supply

7.3.2
Approach to security of supply modelling

This case study focuses on the demand, generation and interconnector backgrounds in FES 2015. However, it is useful to consider how this has changed from the analysis presented in FES 2014 to understand the impact of updated market intelligence and modelling over the year.

Generation – The starting point is the generation backgrounds in FES 2014. These have been updated to reflect changes at a generator level in line with the latest market intelligence. These changes typically include generator closures and openings and Transmission Entry Capacity (TEC) increases or decreases that have been made since the previous year. This has resulted in an overall reduction of 2.2 GW of installed capacity for 2015/16 when compared with FES 2014.

Interconnectors – All of the scenarios assume 1 GW of net imports to GB from interconnectors for winter 2015/16. This net position is made up of 1.8 GW of imports from Europe and 0.8 GW of exports to Ireland. FES 2014 assumed a position of GB net float, where all imports were matched by exports. This increase in imports is assumed because we recognise that the tightening margins over the next few years will prompt responses from the market, one of which would be increased imports.

Demand – Is largely flat across the scenarios for the coming winter showing only a 0.1 GW difference across the scenarios.

LOLE – The government set the reliability standard for security of supply at 3 hours/year LOLE. The approach taken to calculate security of supply is to firstly examine demand and the generation which is available to meet that demand in line with the 3 hour LOLE standard. We alter assumptions relating to specific generation assets to reflect the uncertainty in the market and provide some meaningful variation across the scenarios.

Supplemental balancing reserve (SBR) and demand side balancing reserve (DSBR)[1] – For winter 2014/15, the SO contracted a total volume of 1.1 GW additional de-rated capability comprising of 1 GW SBR and 0.1 GW DSBR. This was not reflected in the generation backgrounds in FES 2014. The SO has already contracted 2.5 GW of additional capability comprising of 2.3 GW of SBR and 0.2 GW of DSBR for winter 2015/16. In this case study, we present the LOLE values for the scenarios both pre and post-procurement of SBR and DSBR. We have done this to show the most up-to-date view of the short-term outlook, highlighting why it was prudent to procure additional generation and demand side support when offered at a competitive cost.

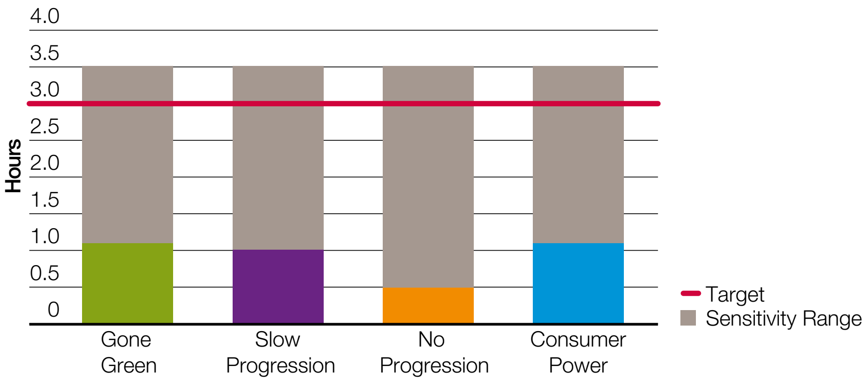
[1] http://www.nationalgridconnecting.com/balancing-act/

7.3.3
Winter 2015/16 LOLE results

Figure 97 shows LOLE across the four scenarios for winter 2014/15 and 2015/16, these figures include capacity contracted via SBR and DSBR for the periods covered.

The supporting narrative begins by looking at the outlook post-procurement of additional capacity. It then explores the position pre-procurement and why it action has been taken.

Figure 97
LOLE chart winter 2015/16 (post-procurement)



The outlook for winter 2015/16 is that in all four scenarios the level of LOLE is below the 3 hour target. This is a slight increase in LOLE from last winter where the LOLE across the scenarios was 0.47hours/year.

For procurement of SBR and DSBR we consider a base case scenario. The base case is FES 2015 **Slow Progression**. We include sensitivities to cover a wide range of credible cases. The selection process determines the optimal volume to procure taking account of this range of credible outcomes and price. This is set out in the Volume Methodology[2] that was approved by Ofgem[3].

[2] http://www2.nationalgrid.com/UK/Services/Balancing-services/System-security/Contingency-balancing-reserve/Methodologies/

[3] https://www.ofgem.gov.uk/ofgem-publications/94680/nbsmethodologyapprovaldecisionletter-pdf

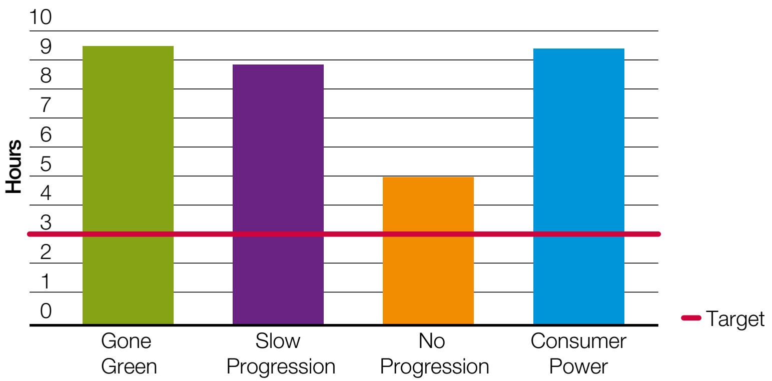
Security of supply

LOLE for winter 2015/16 was higher than than 3 hours/year as shown in Figure 98. Based on analysis of all the credible cases for 2015/16, the optimal procurement volume was determined as 2.5GW of additional de-rated capability. Additional capacity in the form of SBR and DSBR was procured via a tender process. The first tender round was held in December 2014, securing 600MW of SBR and 65MW of DSBR. A second tender round secured an additional 1,784MW of SBR and 112MW of DSBR.

Figure 97 shows the impact of the additional generation obtained through SBR and DSBR contracts on the analysis. All four scenarios show LOLE below the 3 hours/year. When considering the credible cases for 2015/16, the LOLE values range from 0.1–3.5 hours/year. This is shown by the shaded area in Figure 97. This can be compared to the range of LOLE values for winter 2014/15 which was 0–4.3 hours/year.

For the base case scenario pre-procurement LOLE was 8.9hrs which equates to a de-rated margin figure of 1.2%. Following procurement of SBR and DSBR the LOLE in the base case reduces to 1 hour which corresponds to a de-rated margin figure to 5.1%.

Figure 98
LOLE chart winter 2015/16 (pre-procurement)



LOLE values before contracting SRB and DSBR range from 5.1 hours/year in **No Progression** to 9.5 hours/year in **Gone Green**: this is shown in Figure 98. The high levels of LOLE are largely due to a reduction in de-rated generation capacity. The majority of this is thermal plant closing in line with current environmental legislation including the Large Combustion Plant Directive (LCPD)[4] and the Industrial Emissions Directive (IED)[5]. Current market conditions have resulted in a number of CCGT generators closing and mothballing.

The differences between the scenarios are either caused by variations in demand or the underlying assumptions on the level of available generation. For example, **No Progression** assumes an additional 0.8 GW of de-rated capacity in 2015/16 in comparison to the other scenarios. **No Progression** and **Slow Progression** have the lowest demand.

[4] https://www.gov.uk/government/publications/environmental-permitting-guidance-the-large-combustion-plants-directive

[5] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/367365/statutory_security_of_supply_report.pdf – Pages 19 and 20

Security of supply

7.3.4
Summary

We have procured balancing services for winter 2015/16 to ensure we have the tools in place to help us balance the system. This is in line with actions taken for 2014/15. The capacity from generation and these tools shows margins of 5.1% and an LOLE of 1.1 hours/year. The unit cost of these services was lower than the previous winter and represents good value for consumers due to competitive tender prices.

We expect the upcoming winter to be manageable. Procurement of the additional generation at this point has removed uncertainty from the market. It has put us in a much stronger position in the run up to winter 2015/16.

Looking forward to 2018/19, the first delivery year of the capacity market, it is important that we continue to monitor security of supply. We are positioned to identify potential reductions in security of supply. We continue to work closely with Ofgem, government and stakeholders across the energy industry to explore options and products to resolve any gap in a timely and cost effective manner.

The SO is not currently licensed to procure SBR and DSBR services beyond winter 2015/16. We will therefore be consulting with the industry during July 2015. This will consider whether the SBR and DSBR arrangements should be extended, whether changes are required or whether an alternative solution should or could be developed in an appropriate timescale.

Green lights for electricity storage

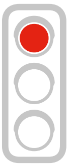
7.4
Electricity storage

Electricity storage could be significant for the future balancing toolkit. It has the potential to offer valuable services to the SO, broader industry, and ultimately the end consumer. Using a traffic light system, this case study explores the developments that could improve the commercial viability of electricity storage in GB. The findings will inform how electricity storage is captured in future years of the FES using an evidenced-based approach. We have considered four areas where progress would be beneficial:

- policy and regulatory developments
- system needs
- commercial developments
- technological developments.

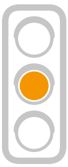
For each area, we explore the current status for GB (**red**, **amber**, **green**). We explain what progress, or '**green**', may look like for GB and consider international examples. Issue resolution, or a '**green**' status, is not necessary for all four areas for storage to be commercially viable; a change in just one or two areas could unlock the potential.

We would like to use this case study as an opportunity to engage with the energy industry. What do you see as the main changes required to improve the commercial viability of electricity storage?



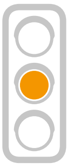
1

Policy and regulatory developments is red



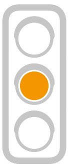
2

System need is amber



3

Commercial developments is amber



4

Technological developments is amber

Green lights for electricity storage

7.4.1
Policy and regulatory developments

The first of the potential areas for development is policy and regulation. This section explores how the absence of a regulatory definition for storage impacts ownership and business models. We also look at the current level of support for storage in GB and internationally.

Current status for GB: red
Storage has been identified as one of the government's "eight great technologies", which are anticipated to propel the UK to future growth in light of their potential to save money and reduce emissions. To date, DECC's Innovation Programme has provided three routes to support the development of electrical energy storage, totalling £56 million.

Although the potential benefits of storage have been established, support remains focused on innovation funding and demonstration projects, rather than through a policy instrument such as incentives, due to the relative infancy of some storage technologies.

One of the challenges facing storage is the absence of a regulatory definition. Electricity storage is not recognised explicitly in EU legislation and is therefore treated as a subset of power generation. This legal uncertainty has implications for ownership and operation, and therefore business models for storage. As transmission system operators (TSOs) are prohibited from controlling generation, this restriction extends to storage. It also results in double charging, where storage is charged for both consuming (charging) and generating (discharging) energy, impacting on operating costs and therefore profit levels.

Greater regulatory clarity could improve the environment for storage, and more targeted support – for example, mandates and incentives – could provide certainty for early adopters in the short- to medium-term. This would be '**amber**' or '**green**'. There are parallels that can be drawn between the regulatory treatment of storage and interconnection. Interconnection was not initially defined within the legislative framework. However, its amended status as 'network' has resulted in cost reflective charging. This change was driven by recognition of the wider benefits interconnection could offer and it may be appropriate to conduct similar assessments for storage.

Practical applications: benefits of storage being treated as an independent asset class
In the US, storage has been identified as a solution to managing the variability of renewable generation, in addition to providing ancillary services and an economically viable alternative to gas peaking plants.

California has a target to procure 1.3GW of electricity and thermal storage by 2020. Along with orders introduced by the Federal Energy Regulatory Commission (FERC), these measures mean storage is no longer competing with conventional power generation, revenue is increased based on speed and accuracy, and connections for storage are fast-tracked. This is bridging the gap between the current relatively high cost of storage and the value to network operators, utilities and consumers.

1 https://www.gov.uk/government/speeches/energy-storage-innovation-showcase
2 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31996L0092:EN:HTML
3 http://www.greenbiz.com/blog/2013/12/11/inside-california-energy-storage-mandate

7.4.2
System need

This section explores transmission system needs that could be addressed by storage. These relate to system operability (frequency, voltage, inertia) and constraint management. The impact of distributed solar PV and wind at times of low demand is pertinent. This topic is discussed in Commercial Developments and you can read more in the Balancing Challenges case study on pages 180–185.

Current status for GB: amber

As described in National Grid's 2014 System Operability Framework[4] (SOF), Summer Outlook Report[5] and the Balancing Challenges case study (page xx), future system requirements are evolving. The Balancing Challenges chapter shows how distributed generation exporting onto the grid at times of low demand has implications for energy balancing and system operability. These challenges arise as output is driven by fuel availability, for example sunshine, rather than market behaviour. Storage, both large scale and domestic, has the potential to alleviate this challenge and unlike interconnection, will not be impacted by European countries experiencing the same issue at similar times of day.

The 2014 SOF has identified other potential future requirements for system operability, which could be met by storage. For example, based upon FES 2014, enhanced frequency response is required at the earliest by 2019/20 in a **Gone Green** world and by 2029/30 at the latest for **No Progression**.

Rapid frequency response can be delivered by interconnectors, wind generators, DSR and energy storage. This suggests that, whilst most storage technologies excel in speed of response, storage is likely to be part of the toolkit in future, rather than the single solution.

Constraint management is required where there is congestion on the transmission system due to excess generation. Storage can be used to integrate large scale renewable generation by absorbing the excess generation and storing it until there is sufficient capacity on the system to release it. The cost of storage is a barrier to this application. In addition, the relationship with incentives for wind generation may dampen the demand for storage. At present, renewable electricity is not eligible for incentives if it is used to charge storage before it enters the electricity system.

For this section, the question is not whether there is a system need, but rather whether storage can provide a cost-effective solution to that need. Whilst storage technologies have the potential to assist with system operability and constraint management, services must be met by the most economic option. Therefore, '**green**' for system need cannot be achieved in isolation. As future system challenges and requirements become clearer, progress will be required in other areas to enable storage to provide services at competitive prices and realise its potential.

Practical applications: SO-owned storage provides solution to requirements

The Italian SO (Terna) has installed a series of batteries to increase the safety of the grid on islands and reduce grid congestion on the mainland. In light of EU legislation, Terna was given authorisation by the Regulatory Authority for Electricity and Gas. Transmission infrastructure was considered. However, due to the risk of over-investment, battery storage was identified as the best short-term solution.

[4] http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/System-Operability-Framework/

[5] http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/FES/summer-outlook/

Green lights for electricity storage

7.4.3 Commercial developments

This section considers barriers to accessing multiple, or stacking, revenue streams and the possibility that storage could receive additional revenue from the provision of a unique service. We also explore how installing storage with distributed generation can increase self-consumption and that price signals are likely to be required to make this worthwhile for consumers.

Current status for GB: amber

The potential revenue streams for storage in GB include providing ancillary services to the SO, deferral of both transmission and distribution network reinforcement, and integrating large scale renewable generation. Stacking revenue streams improves the commercial viability of storage. However, there are a number of barriers to overcome, some of which are being explored by industry groups and innovation projects.

Storage has valuable characteristics, such as speed of energy delivery or absorption, and could therefore provide frequency response services to the SO. Due to the fundamental importance of these services to real-time system security, they must often be provided exclusively so the SO has certainty that a provider will be available when needed. This is often seen as a barrier to stacking revenue streams. Currently some storage providers in GB overcome this by separating their storage into individual units to provide separate services. However, this is not possible for all technologies, and does not fully address the underlying issue of providing more than one service from the same storage volume.

Although commercial changes could enable stacking revenue streams, this may also benefit other market participants in addition to storage providers and, as a result, counteract the advantage storage stands to gain. Therefore, if storage were able to provide a unique and valuable service, such as speed of response, this would be an effective way to enhance its commercial viability.

Storage is used in Italy by the SO to defer transmission network reinforcement. There is not currently a business model to enable storage to access revenue from this service in GB. However, resolving the classification issues raised in policy and regulation could allow storage to provide a cost-effective alternative to traditional reinforcement under the new network options assessment process of the Integrated Transmission Planning and Regulation (ITPR) project.

In addition, UK Power Networks' Low Carbon Network Fund (LCNF) Smarter Network Storage project is investigating how a battery could provide an alternative to traditional distribution network reinforcement and is exploring potential business models and regulatory implications. The battery will also be used to provide ancillary services to the SO and energy services to the wholesale market.

In addition to storage connected to the transmission and distribution networks, we have considered the commercial developments that may be required for smaller scale storage. Installing storage alongside distributed generation enables consumers to be responsive to price signals and can increase self-consumption by decoupling the timing of generation and usage. This reduces the need to buy electricity from the grid at times of peak demand and helps to smooth the daily demand profile. Solar PV can reduce the amount of electricity required from the grid by approximately 30% for a household.

If a battery is added, this reduction is increased to 70-80%[6].

This system has economic benefits when the cost of purchasing electricity exceeds the cost of installing a solar PV and storage system. Bloomberg New Energy Finance (BNEF) suggests that, without dramatic cost reductions in storage technology, the value for storage is in the price differential between peak and off-peak prices.[7] This price differential is unlikely to exist without time of use tariffs (TOUTs) and, at present, the most economic option is a PV system without storage.

Developments for in-home storage

In April 2015, Tesla announced the launch of its new in-home battery. Powerwall is a rechargeable lithium-ion battery designed to store energy at domestic level. It has the potential to be used for load shifting, backup power, and pairing with solar power generation to enable self-consumption. The product is available in two sizes: 7kWh and 10kWh. To provide context, the average daily consumption for a UK household is approximately 11kWh.

Powerwall will be on sale in the US from this summer and 38,000 units have already been reserved by US residents. Due to the unexpected low cost in relation to similar systems, this could be a significant development for storage.

There are currently no plans to sell the product in the UK. However, the balancing challenges discussed earlier in this chapter will require a solution in the very near future and pairing storage with solar generation is therefore a potential growth area within GB.

In the UK, Moixa's Maslow battery is available, as either a 2kWh or 3kWh system. This is a smart energy storage system for residential and commercial applications, which charges during off-peak hours when energy prices are lower or directly from on-site renewables, such as solar generation. Moixa has deployed 0.5MWh across 250 sites under a DECC-funded 2013 demonstration project.

In-home storage will need to make economic sense to most, if not all, of those who purchase devices like Tesla's. However, the media attention the launch of the Powerwall has received suggests desirability could be an increasingly influential factor in the uptake of such products.

38,000

Number of units reserved by US residents for the Powerwall battery

[6] Bloomberg New Energy Finance (BNEF) "European end-user storage: a battery in every home."

[7] BNEF – US residential PV & storage: case against grid defection

Green lights for electricity storage

Although Tesla have been selling residential storage since 2011 under California's Self Generation Incentive Programme, their recently announced Powerwall home battery provides the technology for a far lower cost than many expected, which could drive competition in the market.

Considering these factors, '**green**' will involve changes that overcome the barriers to stacking revenue streams or ensuring that the existing revenue streams are sufficiently attractive in isolation. This could involve changes to service parameters or the introduction of specific markets that value the unique attributes of storage projects. The emergence of a business model, possibly as a result of regulatory change, for storage to provide an alternative to traditional network reinforcement could also represent a '**green**' light. For solar and storage as a model, the introduction of TOUTs and smart meters would sharpen the price differential between peak and off-peak prices, encouraging self-consumption. Our projections for the smart meter roll-out in GB are shown in Figure 40.

Practical applications: investigating how to optimise services from storage and support for domestic generation with storage
At the Dietikon Power Plant, Switzerland, a 1MW battery has been installed and is expected to benefit from multiple revenue streams. This is possible as the battery is integrated with an energy conversion system allowing it to operate in five modes. Peak shaving, frequency control, PV smoothing and voltage control can be achieved from the same asset. The project will shed light on how to develop algorithms that optimise the operation of the storage system.

Subsidies for residential battery systems were introduced in Germany in May 2013. In the first year of the subsidy, over 4,000 new solar and storage systems were installed. Although there are questions over whether this is the most sustainable way to grow the market, this may be a short-term solution to support early adopters.

7.4.4 Technological developments

This section captures improvements in cost, efficiency and lifespan of existing technologies, and the emergence of new technologies.

Current status for GB: amber

The cost of storage is often referred to as a significant barrier. In terms of levelised cost of electricity (LCoE), which represents an "all-in" cost, pumped hydro is currently the most attractive electricity storage technology for delivery of short bursts of energy. The LCoE of compressed air and liquid air energy storage is marginally higher than pumped hydro, and the LCoE for batteries is significantly greater. However it is suggested that the cost of lithium-ion batteries could largely rival that of mechanical storage for power-intensive applications (short bursts) by 2030, with further cost reductions anticipated as deployment increases.

Examples of efficiency improvements include adiabatic systems, where waste heat is stored and reused during the power recovery process, removing the need for fossil fuels. RWE's ADELE project[8] (Germany) is exploring this approach for compressed air energy storage and aims to increase efficiency from around 50% to 70%.

Flywheels are highly efficient and fast responding storage technologies. Whilst they are sometimes used for uninterruptable power supplies (UPS) at data centres in GB, the 20MW flywheel due to be built in County Offaly, Ireland, will be Europe's first grid connected hybrid system. The project is due to launch commercially in 2017[9].

These are promising efficiency improvements and cost projections for existing energy storage technologies. There is also the possibility of the emergence of new technologies that could offer significant enhancements to the storage industry – for example, metal-air batteries. Considering these factors, a strong indicator of '**green**' would be a reduction in LCoE to the point where storage is cost competitive with alternative solutions for the application in question. Examples of these alternatives include interconnection for energy balancing, thermal generation or DSR for ancillary services, and traditional reinforcement for upgrade deferral.

[8] http://www.rwe.com/web/cms/mediablob/en/391748/data/364260/1/rwe-power-ag/innovations/Brochure-ADELE.pdf

[9] http://www.theguardian.com/environment/2015/apr/08/new-energy-storage-plant-could-revolutionise-renewable-sector

Green lights for electricity storage

7.4.5 Conclusions

The commercial viability of storage is strongly linked to cost competitiveness. This could be achieved through a number of routes, including capital cost reductions, incentives or stacking of revenue streams. **Therefore, only one or two of the developments listed below may be needed to unlock the potential of electricity storage and trigger the inclusion of storage within the FES:**

- legislation that recognises electricity storage as a separate entity
- additional targeted policy support, in addition for innovation funding, such as an incentive or mandate for early adopters
- a business model for storage to provide an alternative to traditional network reinforcement
- the introduction of time of use tariffs and smart meters to encourage self-consumption
- the development of frameworks that enable storage providers to provide services to multiple parties
- the continued trend of cost reductions.

We will continue to assess the role of storage in the scenarios and welcome your feedback through stakeholder workshops and bilateral meetings. The successful applications of storage internationally and emerging requirements nationally highlight the opportunities for storage in GB and the potential value that storage could deliver to the energy industry and end consumers.

Chapter eight

Appendix 1
Government policy

CRC Energy Efficiency Scheme (CRC)
The Carbon Reduction Commitment (CRC) Energy Efficiency Scheme[1] is a mandatory scheme aimed at improving energy efficiency and cutting emissions in large public and private sector organisations. The scheme features a range of reputational, behavioural and financial drivers, which aim to encourage organisations to develop energy management strategies that promote a better understanding and more efficient use of energy.

Electricity Market Reform (EMR)
Electricity Market Reform[2] includes the introduction of new long-term contracts: Contracts for Difference (CfDs) for new low carbon generation projects, a Carbon Price Floor[3] (in place since April 2013) and a Capacity Market, to include demand response, interconnectors and generation. EMR also includes an Emissions Performance Standard (EPS), set at 450gCO_2/kWh, to reinforce the requirement that no new coal-fired power stations are built without carbon capture and storage (CCS) and to ensure necessary investment in gas can take place. The Energy Act of 2013 gave the Secretary of State for Energy and Climate Change the power to introduce these elements of EMR (to work alongside the Carbon Price Floor[1]).

National Grid as the National Electricity Transmission System Operator (NETSO) has been appointed as the Delivery Body for EMR. This involves administering the Capacity Market and CfDs on behalf of DECC, as well as providing key analysis to inform decision making.

Our analysis of EMR is ongoing. We have taken account of the main themes in deriving our power supply backgrounds, shown in chapter 5. We assume that the mechanisms will play a part in maintaining adequate plant margins and will ensure that there is sufficient renewable and low carbon generation to meet the renewable and carbon targets in the **Gone Green** scenario.

Feed-In Tariffs scheme (FIT)
The Feed-In Tariffs scheme[4] aims to encourage small scale renewable and low carbon electricity generation by paying users for each unit of electricity generated, as well as a payment for each unit exported to the grid. The scheme is applicable to a number of technologies (solar PV, wind, hydro, and anaerobic digestion) up to a maximum capacity of 5MW of total installed capacity (TIC). Micro combined heat and power (mCHP) plants are also eligible up to 2kW.

Green Deal Energy Company Obligation (ECO)
Green Deal[5] replaces the Carbon Emissions Reduction Target[6] (CERT). It allows individuals and businesses to make energy efficiency improvements to their buildings at no upfront cost through access to the finance needed for the improvements with repayment, in instalments, attached to the electricity bill. Research conducted by GfK NOP showed that in November 2013, 23% of consumers were aware of the Green Deal[7]. It is estimated that 26 million homes could be eligible for Green Deal financing. By the end of March 2015, over 530,000 Green Deal assessments had been carried out, 184 authorised Green Deal providers had been registered and 2,258 organisations were signed up to carry out installations[8].

[1] https://www.gov.uk/crc-energy-efficiency-scheme-qualification-and-registration#overview
[2] https://www.gov.uk/government/policies/maintaining-uk-energy-security--2/supporting-pages/electricity-market-reform
[3] The carbon price floor was legislated for in the 2011 Finance Act
[4] https://www.gov.uk/feed-in-tariffs
[5] https://www.gov.uk/green-deal-energy-saving-measures
[6] http://webarchive.nationalarchives.gov.uk/20121217150421/www.decc.gov.uk/en/content/cms/funding/funding_ops/cert/cert.aspx
[7] https://www.gov.uk/government/publications/green-deal-household-tracker-wave-3
[8] https://www.gov.uk/government/collections/green-deal-and-energy-company-obligation-eco-statistics

Energy Company Obligation (ECO)
The Energy Company Obligation (ECO) commenced in 2013 and will operate until March 2017. It places a legal obligation on energy suppliers to satisfy energy efficiency and fuel saving targets to households. ECO is primarily focused on households unable to achieve significant energy savings from Green Deal without an additional or different measure of support. ECO is directed towards vulnerable and low-income households, community schemes, and those living in harder to treat properties, such as those with solid walls.

Industrial Emissions Directive (IED)
The Industrial Emissions Directive[9] is a European Union directive which commits member states to control and reduce the impact of industrial emissions on the environment post-2015 when the Large Combustion Plant Directive (LCPD) expires.

Under the terms of the IED, affected plant can:
- Opt out and continue running under previous (LCPD) emission limits.
- Opt in under the Transitional National Plan (TNP), which will impose a cap on annual mass nitrogen oxide emissions and a decreasing cap on annual mass sulphur dioxide emissions on all plants operating under a country's TNP until mid-2020. At that point they will have to decide whether to fit appropriate emission-reducing equipment to comply with the directive, be limited to run a maximum of 1,500 hours a year or close.
- Opt in and comply fully from 1 January 2016. This will mean fitting selective catalytic reduction equipment or additional flue-gas de-sulphurisation technology for some plants.

Large Combustion Plant Directive (LCPD)
The Large Combustion Plant Directive[10] is a European Union directive which introduced measures to control the emissions of sulphur dioxide, oxides of nitrogen and dust from large combustion plant. Large power stations (installed capacity greater than 50 MW) in the UK must comply with the LCPD. Plants that 'opt out' of meeting the new standards must close by 2015 or after 20,000 hours of operation.

Levy Control Framework (LCF)
The Levy Control Framework[11] caps the annual amount of money that can be levied on bills to support UK low carbon generation at £2.35bn in 2012/13, rising to £7.6bn in 2020/21. This covers Feed-in Tariffs (FITs), Renewables Obligation (RO) and Contracts for Difference.

Renewable Heat Incentive (RHI)
The Renewable Heat Incentive[12] scheme provides payments for heat generated from renewable technologies including biomass boilers, solar thermal and heat pumps. There are three distinct phases of financial support:

- RHI Phase 1 – for commercial, industrial, public, not-for-profit and community generators of renewable heat
- RHI Phase 2 – a renewable heat premium payment (RHPP) to householders who have no access to the gas network and who generate renewable heat. Under RHPP householders receive a single payment for the installation of renewable heat technology
- RHI Phase 3 – for householders generating renewable heat. Householders will receive regular annual or quarterly payments for heat generated.

[9] http://www.official-documents.gov.uk/document/hc1012/hc16/1604/1604.pdf (page 12)

[10] https://www.gov.uk/government/publications/environmental-permitting-guidance-the-large-combustion-plants-directive

[11] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48244/3290-control-fwork-decc-levyfunded-spending.pdf

[12] https://www.gov.uk/government/policies/increasing-the-use-of-low-carbon-technologies/supporting-pages/renewable-heat-incentive-rhi

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Government policy

Renewables Obligation (RO)
The Renewables Obligation[13] (RO) is the main support mechanism for renewable electricity projects in the UK. Smaller scale generation is mainly supported through the Feed-in Tariff scheme (FITs).

The RO came into effect in 2002 in England and Wales, and Scotland, followed by Northern Ireland in 2005. It places an obligation on UK electricity suppliers to source an increasing proportion of the electricity they supply from renewable sources.

Renewables Obligation Certificates (ROCs) are green certificates issued to operators of accredited renewable generating stations for the eligible renewable electricity they generate. Operators can trade ROCs with other parties. ROCs are ultimately used by suppliers to demonstrate that they have met their obligation.

Where suppliers do not present a sufficient number of ROCs to meet their obligation, they must pay an equivalent amount into a buy-out fund. The administration cost of the scheme is recovered from the fund and the rest is distributed back to suppliers in proportion to the number of ROCs they produced in respect of their individual obligation.

Energy Saving Opportunities Scheme (ESOS)
The government established ESOS[14] to implement Article 8 (4-6) of the EU Energy Efficiency Directive (2012/27/EU). The ESOS Regulations 2014 give effect to the scheme.

ESOS is a mandatory energy assessment scheme for organisations in the UK that meet the qualification criteria. The Environment Agency is the UK scheme administrator.

Organisations that qualify for ESOS must carry out ESOS assessments every 4 years. These assessments are audits of the energy used by their buildings, industrial processes and transport to identify cost-effective energy saving measures.

Organisations must notify the Environment Agency by a set deadline that they have complied with their ESOS obligations, the first of which is 5 December 2014.

[13] https://www.ofgem.gov.uk/environmental-programmes/renewables-obligation-ro
[14] https://www.gov.uk/energy-savings-opportunity-scheme-esos

Appendix 2 – Meet the Energy, Strategy & Policy team

Balancing and Markets
We explore the future electricity balancing challenges and opportunities relating to changing generation and demand. We consider the role that technologies such as interconnectors, electricity storage, demand side response and other innovative solutions may play in the future balancing toolkit. Engagement with stakeholders is vital to the development of ourinterconnector scenarios and through industry groups and bilateral meetings we ensure all perspectives are taken into consideration. We welcome your views on balancing the electricity system over coming decades.

Emma Carr
Balancing and Markets Manager

Dave Wagstaff
EMR Network Cost Analyst

Iain Ashworth
Balancing Analyst

Matthew Speedy
Balancing Analyst

Rhiannon Grey
Balancing Analyst

EMR Modelling
Our team was set up to fulfil part of National Grid's obligations as Electricity Market Reform (EMR) Delivery Body. Our responsibilities include analysis used to recommend the capacity to procure in the Capacity Market that is published annually in our Electricity Capacity Reports and modelling to inform the setting of strike prices for Contracts for Difference (CfDs) as illustrated by our report for the EMR Delivery Plan. We also carry out related modelling work outside of our EMR responsibilities, for example to inform the volume of the new balancing services (SBR and DSBR) required in the mid-decade years.

Duncan Rimmer
EMR Modelling Manager

Ajay Pandey
EMR Senior Data Officer

Gareth Lloyd
EMR Analytical Manager

Simon Geen
EMR Analytical Manager

Gas Demand
As the gas demand team we project the usage of gas for both the Industrial and Commercial markets and the residential sector. We utilise various modelling tools and techniques to support our analysis alongside taking part in several industry discussion groups to balance our statistical analysis with innovative thinking on the future of gas. Heat forms a significant part of our analysis as this is currently dependent on gas in addition to transport which has the potential to become more reliant on gas. Amongst our stakeholders, we engage with gas providers and distribution networks to ensure we're using the most up to date information. If you can share any views on gas demand, please get in touch.

Iain Shepherd
Energy Demand Analyst

Phil Clough
Gas Demand Analyst

Rob Nickerson
Senior Gas Demand Analyst

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Appendix 2 – Meet the Energy, Strategy & Policy team

Gas Supply
We take gas demand projections from our colleagues in the Gas Demand team and work out how much gas will have to come from different sources to meet the demand. Our work depends very much on detailed industry knowledge rather than complicated mathematical modelling, and is helped by the 70 years of industry experience that we have between us. During the year we talk to major industry players, producers, terminal operators, other network operators and potential developers. We also attend industry discussions, all to make sure that we are working with the best possible information when we come to make our supply to demand match. If you have anything that you think we should know about possible gas supplies we'd be very interested to hear from you.

Simon Durk
Gas Supply Manager

Nigel Bradbury
Primary Energy Analyst

Chris Thompson
Senior Gas Supply Analyst

Christian Parsons
Gas Supply Analyst

Market Outlook
We bring together expert thinking, market data, industry experts, stakeholder feedback and indepth analysis to create a rounded view of the future of energy. Our publications cover the short, medium and longer-term including the Winter and Summer Outlook Reports, the Winter Consultation, the Safety Monitors Report and, of course, the Future Energy Scenarios (FES). Our role is to extract the key messages from the inputs and analysis to give a clear direction to National Grid and the industry on energy trends, landscapes and the future energy challenges. We also produce the Stakeholder Feedback document that summarises views from interested parties on the FES document and provides a commentary of how these responses have been used to develop and progress the scenarios. We welcome your views on the content of all these documents.

Catherine Lange
Market Outlook Manager

Andy Dobbie
Energy Security Analyst

Caroline Kluyver
Content Officer

Chris Thackeray
Content Officer

Duncan Sluce
Energy Security Analyst

Faye Relton
Strategy Analyst

Power Demand
We spend much of our time striving to understand electricity usage once it's been generated. Our models are concerned with what people do with electricity in their day-to-day lives, from the home to the office and beyond, from an annual basis right down to an understanding of within day usage profiles. This considers the future landscape for transport, heating and lighting. To understand potential electricity usage, we engage with members of Britain's society, including homeowners, business people, academics and journalists. We also regularly attend a wide range of industry events and conferences along with reading a wide range of publications and annual reports. Please let us know your thoughts and opinions on power demand and how this may change into the future.

Russell Fowler
Power Demand Manager

Huw Thomas
Power Demand Analyst

Kein-Arn Ong
Senior Power Demand Analyst

Orlando Elmhirst
Senior Power Demand Analyst

Power Supply
We consider the sources of generation that will be used to meet power demand now and in the future. We consider all sources of generation (both established and emerging technologies) irrespective of where and how they are connected. We consider how the political ambition, environmental legislation, the economic climate, technological advancements and social engagement influence electricity generation. We look forward to discussing with you our power supply scenarios and will be delighted to hear from you if you have any information on power supply which could be included in our analysis.

Lilian MacLeod
Power Supply Manager

Dr Giuliano Bordignon
Senior Power Economics Analyst

Greg Hunt
Senior Power Supply Analyst

Janet Coley
Senior Power Supply Analyst

Luke Cutler
Power Supply Analyst

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Secondments

Liana Cipcigan
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Leadership team

Roisin Quinn
Head of Energy, Strategy and Policy

Janet Mather
Demand and Supply Manager

Kirsty Martin
PA to Head of Energy, Strategy and Policy

Marcus Stewart
Energy Supply Manager

Nigel Fox
Strategy Development Manager

Appendix 3
Glossary

Acronym	Word	Description
ACT	Advanced conversion technology	Gasification, pyrolysis or anaerobic digestion, or any combination of those.
ASHP	Air source heat pump	Air source heat pumps absorb heat from the outside air. This heat can then be used to produce hot water or space heating.
ARA	Amsterdam Rotterdam and Antwerp (Coal Price)	The cost of coal in the major NW Europe coal importing ports of Amsterdam/Rotterdam/Antwerp (ARA). http://www.worldcoal.org/resources/coal-statistics/shipping-terms-glossary/
AD	Anaerobic digestion	Bacterial fermentation of organic material in the absence of free oxygen.
	Ancillary services	Services procured by a system operator to balance demand and supply and to ensure the security and quality of electricity supply across the transmission system. These services include reserve, frequency control and voltage control. In GB these are known as balancing services and each service has different parameters that a provider must meet.
	Annual power demand	The electrical power demand in any one fiscal year. Different definitions of annual demand are used for different purposes.
ACS	Average cold spell	Average cold spell: defined as a particular combination of weather elements which gives rise to a level of winter peak demand which has a 50% chance of being exceeded as a result of weather variation alone. There are different definitions of ACS peak demand for different purposes.
BBL	Balgzand Bacton Line	A gas pipeline between Balgzand in the Netherlands and Bacton in the UK. http://www.bblcompany.com
	Baseload electricity price	The cost of wholesale electricity paid for baseload power.
bcm	billion cubic metres	Unit or measurement of volume, used in the gas industry. 1 bcm = 1,000,000,000 cubic metres
	Biogas	Biogas is a naturally occurring gas that is produced from organic material and has similar characteristics to natural gas.
	Biomethane	We use the term biomethane specifically for biogas that is of a suitable quality to be injected into distribution or transmission networks. http://www.biomethane.org.uk/
	Boil-off	A small amount of gas which continually boils off from LNG storage tanks. This helps to keep the tanks cold.
CM	Capacity Market	The Capacity Market is designed to ensure security of electricity supply. This is achieved by providing a payment for reliable sources of capacity, alongside their electricity revenues, ensuring they deliver energy when needed.
CCS	Carbon capture and storage	Carbon (CO_2) Capture and Storage (CCS) is a process by which the CO_2 produced in the combustion of fossil fuels is captured, transported to a storage location and isolated from the atmosphere. Capture of CO_2 can be applied to large emission sources like power plants used for electricity generation and industrial processes. The CO_2 is then compressed and transported for long-term storage in geological formations or for use in industrial processes.
CO_2	Carbon dioxide	Carbon dioxide (CO_2) is the main greenhouse gas and the vast majority of CO_2 emissions come from the burning of fossil fuels (coal, natural gas and oil).
CPF	Carbon price floor	A price paid by UK generators and large carbon intensive industries for CO_2 emissions.
CPS	Carbon price support	A price paid by UK generators and large carbon intensive industries in addition to the EU ETS to guarantee a minimum floor price for CO_2 emissions.
CRC	Carbon Reduction Commitment	See appendix on government policy. The Carbon Reduction Commitment is a mandatory scheme aimed at improving energy efficiency and cutting emissions in large public sector and large private sector organisations.
	Cash out	Prices that are used to settle the difference between contracted generation or consumption and the amount that was actually generated or consumed in each half hour trading period

Acronym	Word	Description
	Climate change targets	Targets for share of energy use sourced from renewable sources. The 2020 UK targets are defined in the Directive 2009/28/EC of the European Parliament and of the Council of the European Union, see http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32009L0028&from=EN#ntc1-L_2009140EN.01004601-E0001
CBM	Coal bed methane	Coal bed methane is methane that is extracted from un-mined coal seams by drilling wells directly into the seams to release the gas. http://www.worldcoal.org/coal/coal-seam-methane/coal-bed-methane/
COP	Coefficient of performance	The ratio of heating (or cooling) provided per electrical energy consumed.
CCGT	Combined cycle gas turbine	Gas turbine that uses the combustion of natural gas or diesel to drive a gas turbine generator to generate electricity. The residual heat from this process is used to produce steam in a heat recovery boiler which in turn, drives a steam turbine generator to generate more electricity.
CHP	Combined heat and power	A system whereby both heat and electricity are generated simultaneously as part of one process. Covers a range of technologies that achieve this.
CFL	Compact fluorescent light	A lighting technology introduced to replace traditional incandescent bulbs. Commonly referred to as energy saving bulbs.
CWV	Composite weather variable	A measure of weather incorporating the effects of both temperature and wind speed. We have adopted the new industry wide CWV equations that take effect on 1 October 2015.
CNG	Compressed natural gas	Compressed natural gas is made by compressing natural gas to less than 1 percent of the volume it occupies at standard atmospheric pressure.
CfD	Contract for Difference	See appendix on government policy. Contract between the Low Carbon Contracts Company (LCCC) and a low carbon electricity generator designed to reduce its exposure to volatile wholesale prices.
DBSR	Demand side balancing reserve	Demand side balancing reserve (DSBR) is a balancing service that has been developed to support National Grid in balancing the system during the mid-decade period when capacity margins are expected to be tight. DSBR is targeted at large energy users who volunteer to reduce their demand during winter week-day evenings between 4 and 8pm in return for a payment. Along with supplemental balancing reserve (SBR), this service will act as a safety net to protect consumers, only to be deployed in the event of there being insufficient capacity available in the market to meet demand.
DSR	Demand side response	A deliberate change to an industrial and commercial user's natural pattern of metered electricity or gas consumption, brought about by a signal from another party.
DECC	Department of Energy and Climate Change	A UK government department: The Department of Energy & Climate Change (DECC) works to make sure the UK has secure, clean, affordable energy supplies and promote international action to mitigate climate change.
	Deterministic	A modelling approach that produces a single view or outcome. This approach has no random elements as all outcomes and inputs are completely determined.
DUKES	Digest of UK Energy Statistics	A DECC publication which contains historic information on energy in the UK.
	Dispatch (aka economic dispatch)	The operation of generation facilities to produce energy at the lowest cost to reliably serve consumers, recognizing any operational limits of generation and transmission facilities.
	Distributed generation	Generation connected to the distributed networks which is equal or greater than 1 MW in size, up to onshore transmission areas' mandatory connection thresholds. The thresholds are 100 MW in NGET transmission area, 30 MW in Scottish Power (SP) transmission area and 10 MW in Scottish Hydro-Electric Transmission (SHET) transmission area.
	Distribution losses	Power losses that are caused by the electrical resistance of the distribution system.
DNO	Distribution network operator	Distribution network operators own and operate gas or electricity distribution networks.

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Acronym	Word	Description
EV	Electric vehicle	An electric vehicle has an electric motor to drive the vehicle. It can either be driven solely off a battery, as part of a hybrid system or have a generator that can recharge the battery but does not drive the wheels. We only consider EVs that can be plugged in to charge in this report.
EMR	Electricity Market Reform	See appendix on government policy. A government policy to incentivise investment in secure, low-carbon electricity, improve the security of Great Britain's electricity supply, and improve affordability for consumers.
ELSI	Electricity scenario illustrator	ELSI is a National Grid tool used to model network constraint costs and interconnector flows.
	Electricity storage technologies	Mechanical (for example, pumped hydro and compressed air), thermal (for example, molten salt), electrical (for example, supercapacitors), electrochemical (various battery types), chemical (for example, hydrogen). Each technology has different characteristics, such as speed and duration of response, scale and maturity status.
ETYS	Electricity Ten Year Statement	The ETYS illustrates the potential future development of the National Electricity Transmission System (NETS) over a ten year (minimum) period and is published on an annual basis.
ETL	Electricity Transmission Licence	A permit which allows transmission companies to own and operate electricity transmission assets. Conditions within the licence place rules on how holders can operate within their licence.
	Embedded generation	Power generating stations/units that don't have a contractual agreement with the National Electricity Transmission System Operator (NETSO). They reduce electricity demand on the National Electricity Transmission System.
ECO	Energy Company Obligation	See appendix on government policy. The scheme places a legal obligation on energy suppliers to help households meet energy efficiency and fuel savings targets.
ECUK	Energy Consumption in the UK	A UK government publication which reviews historic energy consumption and changes in efficiency, intensity and output since the 1970s.
ENA	Energy Networks Association	The Energy Networks Association is an industry association funded by gas or transmission and distribution licence holders.
ESOS	Energy Savings Opportunity Scheme	See appendix on government policy. The Energy Savings Opportunity Scheme is a mandatory energy assessment scheme for qualifying organisations in the UK.
	Error correcting model	A model with the characteristics that the deviation of the current state from its long-run relationship will be fed into its short-run dynamics.
EU ETS	EU Emissions Trading Scheme (EU ETS)	A European Union trading scheme that allows participants to buy and sell carbon emissions allowances. https://www.gov.uk/eu-ets-carbon-markets
ENTSO-E	European Network of Transmission System Operators – Electricity	ENTSO-E is an association of European electricity TSOs. ENTSO-E was established and given legal mandates by the EU's Third Legislative Package for the Internal Energy Market in 2009, which aims at further liberalising electricity markets in the EU.
EU	European Union	A political and economic union of 28 member states that are located primarily in Europe.
FiT	Feed-in Tariffs	See appendix on government policy. Government programme designed to promote the uptake of a range of small-scale renewable and low-carbon electricity generation technologies
FIDER	Final Investment Decision Enabling for Renewables	Scheme to help developers of low carbon electricity projects make final investment decisions ahead of the Contract for Difference regime.
FFR	Firm Frequency Response	Firm Frequency Response (FFR) is the firm provision of Dynamic or Non-Dynamic Response to changes in Frequency. http://www2.nationalgrid.com/uk/services/balancing-services/frequency-response/firm-frequency-response/
	Foot room	The ability for a generation plant to allow output to decrease without going below its minimum output level and disconnecting from the system.

Acronym	Word	Description
	Frequency controlled demand management	Frequency control demand management (FCDM) provides frequency response through interruption of demand customers. The electricity demand is automatically interrupted when the system frequency transgresses the low frequency relay setting on site. http://www2.nationalgrid.com/uk/services/balancing-services/frequency-response/frequency-control-by-demand-management/
	Frequency response	An ancillary service procured by National Grid as system operator to help ensure system frequency is kept as close to 50hz as possible. Also known as frequency control or frequency regulation.
FES	Future Energy Scenarios	The FES is a range of credible futures which has been developed in conjunction with the energy industry. They are a set of scenarios covering the period from now to 2050, and are used to frame discussions and perform stress tests. They form the starting point for all transmission network and investment planning, and are used to identify future operability challenges and potential solutions.
GTYS	Gas Ten Year Statement	The GTYS illustrates the potential future development of the (gas) National Transmission System (NTS) over a ten year period and is published on an annual basis.
GW	Gigawatt	1,000,000,000 watts, a measure of power
GWh	Gigawatt hour	1,000,000,000 watt hours, a unit of energy
gCO_2/kWh	Gram of carbon dioxide per kilowatt hour	Measurement of CO_2 equivalent emissions per kWh of energy used or produced
GB	Great Britain	A geographical, social and economic grouping of countries that contains England, Scotland and Wales.
	Green Deal	See appendix on government policy. A scheme that allows individuals and businesses to make energy efficiency improvements to their buildings.
GDHIF	Green Deal Home Improvement Fund	See appendix on government policy. A scheme that allows individuals to get financial support for qualifying energy efficiency improvements to homes.
GHG	Green house gases	A gas in the atmosphere that absorbs and emits radiation within the thermal infrared range.
GDP	Gross Domestic Product	An aggregate measure of production equal to the sum of the gross values added of all resident, institutional units engaged in production (plus any taxes, and minus any subsidies, on products not included in the value of their outputs).
GVA	Gross Value Added	The value of goods and services produced in a sector of the economy
GSHP	Ground source heat pump	Ground source heat pumps absorb heat from the ground. This heat can then be used to produce hot water or space heating.
	Head Room	The operation of generation plant below its minimum output levels to allow output to increase at times of need.
	Heat pump	A heat pump is a device that provides heat energy from a source of heat to a destination called a "heat sink".
HGV	Heavy goods vehicle	A truck weighing over 3,500kg.
HHDI	Household disposable income	Household income minus tax.
IED	Industrial Emissions Directive	See appendix on government policy. The Industrial Emissions Directive is a European Union directive which commits member states to control and reduce the impact of industrial emissions on the environment post-2015 when the Large Combustion Plant Directive (LCPD) expires.
ITPR	Integrated Transmission Planning and Regulation	Ofgem's Integrated Transmission Planning and Regulation (ITPR) project examined the arrangements for planning and delivering the onshore, offshore and cross-border electricity transmission networks. Ofgem published the final conclusions in March 2015.
IUK	Interconnector (UK)	A bi-directional gas pipeline between Bacton in the UK and Zeebrugge Belgium. http://www.interconnector.com

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Acronym	Word	Description
	interconnector, gas	Gas interconnectors connect gas transmission systems from other countries to the National Transmission System (NTS) in England, Scotland and Wales. There are currently three gas interconnectors which connect to the NTS. These are: – IUK interconnector to Belgium – BBL to the Netherlands – Moffat to the Republic of Ireland, Northern Ireland and the Isle of Man.
	interconnector, power	Electricity interconnectors are transmission assets that connect the GB market to Europe and allow suppliers to trade electricity between markets.
IRR	Internal Rate of Return	The annualised rate of return, independent of inflation, for the net present value of an investment of zero in a given time frame.
IEA	International Energy Agency	The International Energy Agency is an intergovernmental organisation that acts as an energy policy advisor to member states.
LCPD	Large Combustion Plant Directive	See appendix on government policy. The Large Combustion Plant Directive is a European Union Directive which introduced measures to control the emissions of sulphur dioxide, oxides of nitrogen and dust from large combustion plant.
LCF	Levy Control Framework	See appendix on government policy. The Levy Control Framework caps the annual amount of money that can be levied on bills to support UK low carbon generation at £2.35bn in 2012/13, rising to £7.6bn in 2020/21. This covers Feed-in Tariffs (FITs), Renewables Obligation (RO) and Contracts for Difference.
LED	Light emitting diode	An energy efficient electronic lighting technology which is increasingly being adopted in UK homes and businesses.
LNG	Liquefied natural gas	LNG is formed by chilling gas to -161˚C so that it occupies 600 times less space than in its gaseous form. www2.nationalgrid.com/uk/Services/Grain-lng/what-is-lng/
	Load Factor	the average power output divided by the peak power output over a period of time.
LDZ	Local Distribution Zone	A gas distribution zone connecting end users to the (gas) National Transmission System.
LOLE	Loss of load expectation	LOLE is used to describe electricity security of supply. It is an approach based on probability and is measured in hours/year. It measures the risk, across the whole winter, of demand exceeding supply under normal operation. This does not mean there will be loss of supply for X hours/year. It gives an indication of the amount of time, across the whole winter, which the system operator (SO) will need to call on balancing tools such as voltage reduction, maximum generation or emergency assistance from interconnectors. In most cases, loss of load would be managed without significant impact on end consumers.
LCCC	Low Carbon Contracts Company	Private company owned by the Department of Energy and Climate Change (DECC) that manages the Contracts for Difference (CFD) scheme introduced by government as part of the EMR programme.
LCHT	Low carbon heating technology	A heating technology that has a lower carbon intensity for heating homes than an A rated condensing gas boiler
LCNF	Low Carbon Network Fund	A fund established by Ofgem to support projects sponsored by the distribution network operators (DNOs) to try out new technology, operating and commercial arrangements.
	Marine technologies	Tidal streams, tidal lagoons and energy from wave technologies (see http://www.emec.org.uk/)
	Medium range storage	These commercially operated sites have shorter injection/withdrawal times so can react more quickly to demand, injecting when demand or prices are lower and withdrawing when higher. http://www2.nationalgrid.com/UK/Our-company/Gas/Gas-Storage/
MWe	Megawatt (electrical)	1,000,000 Watts, a measure of power.
MWh	Megawatt hour	1,000,000 Watt hours, a measure of power usage or consumption in 1 hour.
	Merit Order	An ordered list of generators, sorted by the marginal cost of generation.
mCHP	Micro-Combined Heat and Power	A subset of CHP, designed for domestic use.

Acronym	Word	Description
	Micro generation	Defined within this document as generation units with an installed capacity of less than 1 MW.
mcm	Million cubic meters	Unit or measurement of volume, used in the gas industry. 1 mcm = 1,000,000 cubic metres.
Mte CO_2	Million tonnes of CO_2 equivalent	Carbon dioxide equivalency is a quantity that describes, for a given mixture and amount of greenhouse gas, the amount of CO_2 that would have the same global warming potential (GWP), when measured over a specified timescale (generally, 100 years).
	N-1	Refers to the European Commission security of supply test, where total supply minus the largest single loss is assessed against total peak demand. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:295:0001:0022:EN:PDF
NBP	National balancing point	The wholesale gas market in Britain has one price for gas irrespective of where the gas comes from. This is called the national balancing point (NBP) price of gas and is usually quoted in pence per therm of gas.
	National balancing point (NBP) gas price	Britain's wholesale NBP Gas price is derived from the buying and selling of natural gas in Britain after it has arrived from offshore production facilities. https://www.ofgem.gov.uk/gas/wholesale-market/gb-gas-wholesale-market
NETS	National Electricity Transmission System	It transmits high-voltage electricity from where it is produced to where it is needed throughout the country. The system is made up of high voltage electricity wires that extend across Britain and nearby offshore waters. It is owned and maintained by regional transmission companies, while the system as a whole is operated by a single system operator (SO).
NTS	National Transmission System	A high-pressure gas transportation system consisting of compressor stations, pipelines, multijunction sites and offtakes. NTS pipelines transport gas from terminals to NTS offtakes and are designed to operate up to pressures of 94 barg.
NGV	Natural gas vehicle	A vehicle which uses compressed or liquefied natural gas as an alternative to petrol of diesel.
NOx	Nitrous oxide	A group of chemical compounds, some of which are contributors to pollution, acid rain or are classified as green house gases.
OFGEM	Office of Gas and Electricity Markets	The UK's independent National Regulatory Authority, a non-ministerial government department. Their principal objective is to protect the interests of existing and future electricity and gas consumers.
	Oil & Gas UK	Oil & Gas UK is a representative body for the UK offshore oil and gas industry. It is a not-for-profit organisation, established in April 2007. http://www.oilandgasuk.co.uk
OCGT	Open Cycle Gas Turbine	Gas turbines in which air is first compressed in the compressor element before fuel is injected and burned in the combustor.
	Passivhaus	A Passivhaus is a building, for which thermal comfort can be achieved solely by post-heating or post-cooling of the fresh air mass, which is required to achieve sufficient indoor air quality conditions – without the need for additional recirculation of air.
	Peak demand, electricity	The maximum power demand in any one fiscal year: Peak demand typically occurs at around 5:30pm on a week-day between December and February. Different definitions of peak demand are used for different purposes.
	Peak demand, gas	The 1-in-20 peak day demand is the level of demand that, in a long series of winters, with connected load held at levels appropriate to the winter in question, would be exceeded in one out of 20 winters, with each winter counted only once.
pa	Per annum	per year.
PV	Photovoltaic	A method of converting solar energy into direct current electricity using semi-conducting materials.
PHEV	Plug-in hybrid electric vehicle	Has a battery which can be charged by plugging it in as well as a regular engine.
	Power supply background (aka Generation background)	The sources of generation across Great Britain to meet the power demand.

Appendix 3
Glossary

Acronym	Word	Description
	Pumping demand	The power required by hydro-electric units to pump water into the reservoirs.
PEV	Pure electric vehicle	Has only a battery for energy storage.
RHI	Renewable Heat Incentive	See appendix on government policy. A payment incentive owned by Ofgem which pays owners of certain, renewable heating technologies per unit of heat produced. There is a domestic and a non-domestic version.
ROC	Renewable Obligation Certificate	See appendix on government policy. Green certificates issued to operators of accredited renewable generating stations for the eligible renewable electricity they generate. ROCs are ultimately used by suppliers to demonstrate that they have met their obligation.
RO	Renewables Obligation	See appendix on government policy. Main support mechanism for renewable electricity projects in the UK. It places an obligation on UK electricity suppliers to source an increasing proportion of the electricity they supply from renewable sources.
R&D	Research and development	A general term for activities which involve improvements to goods or processes, or research into new goods or processes.
	Seasonal storage or long-range storage	There is one long-range storage site on the national transmission system: Rough, situated off the Yorkshire coast. Rough is owned by Centrica and mainly puts gas into storage (called 'injection') in the summer and takes gas out of storage in the winter. http://www2.nationalgrid.com/UK/Our-company/Gas/Gas-Storage/
	Self-consumption	Where an end user consumes the electricity they generate, commonly from solar generation. This reduces the need to import electricity from grid but does not necessarily mean an end user is self-sufficient.
	Shale gas	Shale gas is natural gas that is found in shale rock. It is extracted by injecting water, sand and chemicals into the shale rock to create cracks or fractures so that the shale gas can be extracted. https://www.gov.uk/government/publications/about-shale-gas-and-hydraulic-fracturing-fracking
SRMC	Short run marginal cost	The instantaneous variable cost for a power plant to provide an additional unit of electricity. The short run marginal cost (SRMC) is derived from the cost of fuel, the cost of CO_2 emissions, the share of operating and maintenance (O&M) costs that varies with the plant electricity output and any income from incentives and the provision of heat associated to the plant electricity output.
STOR	Short term operating reserve	Short term operating reserve (STOR) is a service for the provision of additional active power from generation and/or demand reduction.
	Smart appliances	Residential power consuming goods which are able to reduce their power demand at defined times of the day either by reacting to a signal or by being programmed.
	Smart meter	New generation gas and electricity meters which have the ability to broadcast secure usage information to customers and energy suppliers, potentially facilitating energy efficiency savings and more accurate bills.
	Station demand	The onsite power station requirement, for example for systems or start up.
	Summer minimum	The minimum power demand off the transmission network in any one fiscal year: Minimum demand typically occurs at around 06:00am on a Sunday between May and September.
SBR	Supplemental balancing reserve	Supplemental balancing reserve (SBR) is a balancing service that has been developed to support National Grid in balancing the system during the mid-decade period when capacity margins are expected to be tight. SBR is targeted at keeping power stations in reserve that would otherwise be closed or mothballed. Along with demand side balancing reserve (DSBR), this service will act as a safety net to protect consumers, only to be deployed in the event of there being insufficient capacity available in the market to meet demand.
	System inertia	The property of the system that resists changes. This is provided largely by the rotating synchronous generator inertia that is a function of the rotor mass, diameter and speed of rotation. Low system inertia increases the risk of rapid system changes.
	System operability	The ability to maintain system stability and all of the asset ratings and operational parameters within pre-defined limits safely, economically and sustainably.

Acronym	Word	Description
SO	System operator	An entity entrusted with transporting energy in the form of natural gas or power on a regional or national level, using fixed infrastructure. Unlike a TSO, the SO may not necessarily own the assets concerned. For example, National Grid operates the electricity transmission system in Scotland, which is owned by Scottish Hydro Electricity Transmission and Scottish Power.
TWh	Terawatt hour	1,000,000,000,000 watt hours, a unit of energy
TOUT	Time Of Use Tariff	A charging system that is established in order to incentivise residential consumers to alter their consumption behaviour – usually away from high power demand times.
tCO^2	Tonne of carbon dioxide	A fixed unit of measurement commonly used when discussing carbon dioxide emissions.
TEC	Transmission entry capacity	The maximum amount of active power deliverable by a power station at its grid entry point (which can be either onshore or offshore). This will be the maximum power deliverable by all of the generating units within the power station, minus any auxiliary loads.
	Transmission losses	Power losses that are caused by the electrical resistance of the transmission system.
TSO	Transmission system operators	An entity entrusted with transporting energy in the form of natural gas or power on a regional or national level, using fixed infrastructure.
	Triad	Triad demand is measured as the average demand on the system over three half hours between November and February (inclusive) in a financial year. These three half hours comprise the half hour of system demand peak and the two other half hours of highest system demand which are separated from system demand peak and each other by at least ten days.
UKCS	UK Continental Shelf	The UK Continental Shelf (UKCS) comprises those areas of the sea bed and subsoil beyond the territorial sea over which the UK exercises sovereign rights of exploration and exploitation of natural resources.
UK	United Kingdom of Great Britain and Northern Ireland	A geographical, social and economic grouping of countries that contains England, Scotland, Wales and Northern Ireland.
UCL	University College London	A UK university based in London.
	Weather corrected	The actual demand figure that has been adjusted to take account of the difference between the actual weather and the seasonal normal weather.

Annual data in FES

Where a single year is referred to in FES, e.g. 2020, we are referring to that calendar year.

Where data is across split years, e.g. 2020/21, we are referring to power years. These run from 1 April to 31 March. For example, 2020/21 refers to 1 April 2020 to 31 March 2021.

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