nationalgrid

Future Energy Scenarios 2018

FAQs

Version 3.0 | 3 September 2018

Our **Frequently Asked Questions** (FAQs) publication is just one of a suite of documents we produce as part of our Future Energy Scenarios (FES) process. A huge amount of work – including modelling, analysis and interpretation – goes into the production of the main document. For ease of use we only highlight significant changes to our modelling methods in the main **FES** document. Alongside this publication, we have the **Scenario Framework** that details all the assumptions and levers that are used as input into our models. Our **Data Workbook** contains all the outputs from the numerous models: the detailed tables, graphs and charts. We also publish a summary document, **FES in 5,** and our **Modelling Methods**. For more information and to view each of these documents visit our website: www.fes.nationalgrid.com

Future Energy Scenarios document suite

This FAQ document seeks to answer the main questions we receive as we publish FES. We will continue to update this document, ensuring the latest question and answers are shared. As with our other FES documents we welcome your feedback, please contact us at: fes@nationalgrid.com

This is version 3.0 which includes questions and answers we received since the launch of FES 2018. **The text that has been added since the previous version is shown in green.**

Contents

General questions

Q: How do I ask questions or seek further information about the Future Energy Scenarios (FES)?

A: Please send questions via email to fes@nationalgrid.com . We will answer your questions as soon as we can.

Q: FES looks different this year compared to last year. What has changed?

A: The main FES document is just one of a suite of documents we produce as part of our FES process. A huge amount of work, including modelling, analysis and interpretation, goes into the production of the main document. For ease of use we have not included all of that data in the main FES document.

Alongside it we have the **Scenario Framework** that details the assumptions and levers that are used as inputs into our models. Our **Data Workbook** contains the outputs from the numerous models: the detailed tables, graphs and charts. We also publish information on our **Modelling Methods**, a summary document **FES in 5** and these **FAQs**. For more information and to view each of these documents visit our website: http://fes.nationalgrid.com/fes-document/

In response to feedback from stakeholders who said they'd find a year-on-year comparison useful, we have prepared a summary document which explains the key changes from FES 2017 to 2018, including a sheet with key statistics.

Q: Where can I find further information about the modelling used for FES?

A: You can find this in our **Scenario Framework** and **Modelling Methods** documents which can be found on our website: http://fes.nationalgrid.com/fes-document/

Q: Where can I find the data published in the FES?

A: The FES charts and the associated data tables are available in the **Data Workbook**, which can be accessed on our website http://fes.nationalgrid.com/fes-document/. The charts are labelled as they are in the main document (e.g. Figure 3.1). We have also published additional datasets in the **Data Workbook**, containing data that supports the FES analysis. The **Data Workbook** uses the following abbreviations:

CP: Commodity Prices
GD: Gas Demand
ED: Electricity Demand
HT: Heating Technologies
RT: Road Transport Demand
ES: Electricity Supply
GS: Gas Supply

Q: What is the date format in the Data Workbook?

A: All Gas Demand and Gas Supply information is in calendar years, with the exception of Gas Peak Demand, which is in gas years. Gas Years run from 1 October to 30 September. All Electricity Demand and Electricity Supply information is in financial years, with the exception of Figure ED2 (Rollout of electricity smart meters, installations per year), which is in calendar years. Road Transport and Heating

Technologies are in Calendar Years. Information on date formats is included in the notes on each relevant worksheet in the Data Workbook.

About the scenarios

Q: If you had to predict the future, which would be the most probable scenario?

A: FES is designed to provide a longer-term view of the range of potential energy landscapes, not to analyse where we are right now. We are not "in" any of the scenarios. The four scenarios we've outlined are based upon pathways beginning today.

Across our industry there is a great degree of uncertainty about the future, including the political, economic, social and technological landscapes. Scenarios are a powerful tool for understanding uncertainty. By providing a range of credible futures, we can be confident that the reality will be captured somewhere within that range. There is too much uncertainty in the future for a credible single view of the future in the timeframe that FES considers, i.e. out to 2050.

Q: Can the scenarios be translated to a regional level?

A: Our Future Energy Scenarios are intended to identify a range of credible scenarios across gas and electricity on a GB-wide basis. In order to support planning of the GB electricity transmission system, we split the GB-level data down into regional data sets using best available data. These data sets are published in November as part of the Electricity Ten Year Statement (ETYS).

In order to provide visibility and transparency of this work, we have published a spreadsheet containing draft regional data for electricity in the four FES 2018 scenarios. This data forms a starting point for our network analysis and should be considered draft at this stage as it may be modified for planning purposes in the subsequent processes. This data can be accessed via our website: http://fes.nationalgrid.com/fes-document/

Q: How will you work with Distribution System Operators (DSOs) in developing scenarios going forward? Will Distribution Network Operators (DNOs) be expected to carry out their own analysis to account for local issues?

A: National Grid as System Operator is currently working with DNOs on an Energy Networks Association (ENA) initiative called the Open Networks project. One of the work streams within Open Networks considers how best to ensure National Grid and DNOs / DSOs work together to develop future scenarios that are both credible and consistent on a "Whole System" basis.

Q: What's more important in your scenario framework, "Keeping the lights on" or "Keeping the climate safe for life to exist"?

A: All our scenarios meet defined security of supply standards (i.e. the 1-in-20 standard for gas and the 3 hours' loss of load reliability standard for electricity) in each year out to 2050 and these standards are not flexed across the FES framework axes. Climate change is largely catered for by the "speed of decarbonisation" axis which was introduced, alongside the decision to make two scenarios compliant with the 2050 carbon reduction target, for FES 2018 following extensive engagement with our stakeholders.

Q: Are the electricity and gas pricing assumptions consistent across each of the scenarios?

A: Our pricing assumptions are determined by the Scenario Framework to ensure consistency across the scenarios and we use the same data provider for the electricity and gas retail prices applied in our commercial and industrial modelling. Another area where this is pertinent is our electricity market modelling. We use BID3 to model the wholesale electricity market in GB and Europe. This assumes costs for fuel and carbon, which are published in our data workbook. Therefore, the gas demand from CCGTs is linked to the fuel price assumptions and the wholesale electricity price (although this is determined by the model, and isn't something that we currently publish).

Carbon reduction targets and air quality

Q: What lead you to have two scenarios that meet the 2050 target? Do you think this is now more likely or are there other drivers (e.g. policy/political focus)? Shouldn't all of your scenarios meet the 2050 target, given that it's legally binding?

A: Our scenarios are a reflection of the current uncertainty levels in the energy industry. Over the last year we have seen significant progress in terms of potential ways to decarbonise, but there is still uncertainty to be resolved as to how the UK's 2050 carbon reduction target can be achieved. As part of our stakeholder engagement, we discussed how many scenarios should meet the target. The consensus was that having more than one scenario meet the target would allow us to explore a greater range of pathways that achieve this goal. At the same time, the feedback also suggested that not all of the scenarios should meet the target in order to show a range of possible outcomes.

You can find out more about this in our Stakeholder Feedback Document on the FES website: http://fes.nationalgrid.com/media/1346/future-energy-scenarios-2018-stakeholder-feedback-document-published-feb-2018.pdf

We will continue to monitor this through market intelligence, policy developments, industry commentators and stakeholder feedback.

Q: Two degrees is an out of date concept as the debate is moving towards 1.5 degrees or net zero targets. Is there a plan to consider these more aggressive targets?

A: We recognise that zero carbon is gathering interest in general and this is something that we will be monitoring and considering the impact to FES as and when appropriate. It is essential that the scenarios reflect credible pathways. In terms of decarbonisation the focus is currently still on the 80% reduction by 2050 based on the current legislation from the Climate Change Act 2008.

Q: UK TIMES produces holistic scenarios. How closely have you kept to the output of UK TIMES and where you have deviated? Can the FES be considered "holistic"?

Some sectors and fuel types are not included in FES outputs, for example, aviation and shipping. UK TIMES outputs could represent FES scenarios to a large extent, reflecting the level of key elements in the four scenarios. With the modelling setup difference, UK TIMES replicates won't be matching FES exactly.

Q: How are the scenarios influenced by the escalating effects of climate change (e.g. drought affecting hydro, storms causing energy spikes etc.)?

A: Historical weather is an important part of the scenarios as it informs annual and peak energy demands. In terms of possible changing weather patterns and impact on energy demand, this is an area we do not currently account for, but we would be keen to receive views on how such climate impacts could be accounted for given the high degree of uncertainty in weather.

Q: What impact do devolved government targets have on the scenarios? Do Scottish targets skew any of the transitions we see in the scenarios?

A: We monitor and note the relevant energy policy under the UK and devolved governments for consideration within our analysis. FES is directly related to GB and needs to take account of the entire country. Many aspects of energy policy come under the devolved governments and as such have potential to differentiate from each other to an extent. However, broadly speaking, the political, economic, technological and social factors underpinning the scenarios are applicable across GB. With regards to the political aspect, we note that Scotland is considering a proposal to increase their carbon reduction targets and Wales has also adopted carbon reduction/renewables targets. Depending on progress of the proposals this will be considered further in future.

Q: Do your scenarios take account of increasing emissions from aviation, e.g. as a result of new runways?

A: No, as in UK TIMES the aviation demand (as modelling input) is from published DfT aviation forecasts, and the current input used in UKTM hasn't explicitly included the impact of new runways.

Q: What granularity is the carbon intensity being provided at?

A: Carbon intensity is provided at annual level, please see our Data Workbook (Tab 5.2_5.3) for carbon intensity figures for four scenarios.

Q: What are your assumptions for CO2 intensity of interconnectors?

A: We assume that the CO2 intensity of interconnectors is zero in our analysis. This is because the standard way of counting emissions is to count those that are within a country's geographical area.

Q: Aren't recent carbon emission reductions the result of coal closures, but isn't additional action required to reduce emissions going forward?

A: The reduction in coal use and the closure of coal plant has contributed to the reductions in carbon seen in recent history. This has helped the UK keep pace with the carbon budgets set by the Climate Change Committee (CCC). Furthermore, the CCC state that UK is on track to meet budgets out to 2022. Beyond this is it not currently clear how UK will meet the carbon budgets. In essence, there is a requirement for the UK to tackle more difficult to decarbonise areas such as domestic heating. This is why we have four scenarios showing different progress toward the targets.

Q: Do you consider the impact on air quality and public health from different technologies (e.g. heat pumps are NOx, SOx and particulate free at the point of use)?

As part of the transport analysis we considered the rise of clean air zones and its impact on changes in ultra-low emission transport. Air quality was not directly modelled as part of the residential heat analysis. However, it was taken into account more generally when considering the use of biomass as a heating technology.

Q: Is NG developing consumer software packages to assist consumers to forecast their transport, electricity and heat needs to ensure demand management works for them?

A: An example of a tool that National Grid is developing to help consumers better understand their energy consumption is the National Grid Carbon Intensity API (http://carbonintensity.org.uk/). The OpenAPI allows consumers and smart devices to schedule and minimise CO2 emissions at a local level.

Brexit and Europe

Q: How do you reflect / model Brexit in your scenarios?

A: The UK's decision to leave the European Union in 2016 has introduced some uncertainty around future energy trading. Given the uncertainty on future trading arrangements, our analysis assumes continued market harmonisation between GB and Europe once the UK has left the European Union. This includes for example that GB continues to participate in the Internal Energy Market, or similar future arrangements are developed. Should further information on future European energy trading arrangements become available, we will consider how any such changes impact our analysis.

Q: Do the FES scenarios take account of future energy scenarios for other countries?

A: This year, we have enhanced our modelling of electricity interconnector flows. We have also modelled the impact of decarbonisation in connected countries. This is based on scenarios developed by other European Transmission System Operators and ENTSO-E – the European Network of Transmission System Operators for Electricity. We have published our sources in the Modelling Methods document. Where appropriate and available, we include energy scenarios developed by other Transmission System Operators, for example, those from Gas Networks Ireland and Gasunie.

Q: What does FES assume regarding the impact of Brexit on the development of, and energy flows through, interconnectors? Is the outcome of Brexit assumed to be the same across all scenarios or is that a variable that's included as well?

A: All of our scenarios assume continued interconnection with Europe. This is because there are benefits to both GB and Europe. Our analysis assumes continued market harmonisation between GB and Europe once the UK has left the European Union. This includes, for example, that GB continues to participate in the Internal Energy Market, or similar future arrangements are developed. We have assumed that market prices will continue to drive flows and that there are no barriers to trade.

Q: What is the impact of Brexit on security of supply in your scenarios?

A: All of our scenarios are consistent with the electricity and gas security of supply standards. This means they meet the electricity security of supply reliability standard of 3 hours loss of load expectation and the N-1 test for gas.

Q: Why is there a significant increase in interconnectors rather than renewables in your scenarios, given Brexit and geopolitical risks to security of supply?

A: In FES 2018, we consider a range of electricity interconnector capacity across our scenarios. GB currently has 4 GW electricity interconnectors and there is 4.4 GW under construction. In addition, there are a number of other projects that have regulatory approval.

Demand

Q: What are your economic growth scenarios?

A: We used Oxford Economics data to feed into our Industrial and Commercial demand model. In this year's FES we have used two economic conditions that have differing growth rates of Gross Domestic Product (GDP). We believe that these economic pathways provide enough flexibility to model the range of future outcomes. The average GDP growth rates over the FES period are shown in Table 4.1 of the main FES document (see below).

Table 4.1
A summary of the key economic levers

Lever	Average GDP growth	Electricity retail prices	Gas retail prices
Community Renewables	2%	High	High
Two Degrees	2%	High	High
Steady Progression	0.9%	Low	Low
Consumer Evolution	0.9%	Low	Low

Q: Should we not look at energy demand in terms of demand for heat, power and transport, rather than gas and electricity?

A: In FES we consider the different components of energy demand such as heat, power and transport as well as the electricity / gas and residential / non-residential aspects. This can be seen in Chapter 4 of the FES Document as well as the FES 2018 Conference presentations which were also structured around the themes of heat, power and transport.

Q: What definition of electricity demand do you use in FES?

A: In FES we consider underlying demand. That is end-consumer demand, regardless of where (transmission, distribution or on site) that electricity is generated, plus network losses. Demand is weather corrected to seasonal normal for annual and average cold spell (ACS) for peak. For clarity, it does not include interconnector exports, station demand, pumping station demand or other forms of storage demand.

At peak, industrial and commercial "true demand reduction" is not deducted from the demand as the extent of response will vary depending on market conditions. Residential home appliance demand reduction is deducted as this is considered to be a behavioural response, rather than a significant response to real time signals. To differing degrees, electric vehicles are assumed to adopt smart charging in all scenarios.

Q: How does this definition of electricity demand differ from other National Grid publications?

A: Other National Grid publications (the Electricity Ten Year Statement (ETYS), the System Operability Framework (SOF) and the Network Options Assessment (NOA)) consider transmission demand, as they look at future development of the transmission system and year-ahead system security of supply. Our outlook documents are now moving to consider end consumer demand (like FES) in order to illustrate the total demand requirement, regardless of how the demand is met. You can find out more about our System Operator publications on our website at: https://www.nationalgrid.com/uk/publications

Q: Where can I find net transmission demand figures?

Historically these have been published with ETYS in November. Following feedback, we have included "National Demand" in the FES Data Workbook. This is demand on the transmission system but without the addition of demands from power stations, pumping, storage or interconnector exports (consumer demand on the GB transmission system).

Q: What definition of gas demand do you use in FES?

A: In FES we consider end-consumer demand, regardless of whether customers are connected to the distribution or transmission network. FES shows annual totals, so we do not include gas injected into storage as gas flows into and out of storage will net to zero over a year. Demand is corrected to seasonal normal weather. In the demand and sensitivity chapters we include demand within GB; exports to Ireland and continental Europe are excluded. When matching gas supply to demand we include gas for export, losses on the distribution and transmission networks, and gas used in the operation of the system.

Q: Which gas-fired power plants are included in the gas demand for power figure published in FES?

A: The FES figure for "gas demand for electricity generation" (Figure 4.25 on page 86 of the main FES 2018 document and Chart 4.25 in the Data Workbook) includes only gas demand for power generation from transmission connected CCGTs, Gas CCS, Gas CHPs, and OCGTs. Distribution level connected gas power plants are counted in the Industrial and Commercial gas demand category.

Q: Should FES look at how energy is used and how it is moved across the system separately, e.g. methane to a reformer, transformed to hydrogen, then electricity generation?

A: FES is the starting analysis for other industry analysis activity. FES is primarily concerned with the possible energy demand requirements and ways to meet that energy. Thereafter, network requirements and operability assessments take place on both the gas and electricity networks to consider how energy flows. These outturn in the Gas & Electricity ten year statements and the respective operability documents (GFOP & SOF)

Q: How many new cars are registered each year in GB?

A: Over the last 3 years (2015, 2016 and 2017) there have been on average 2.6m cars registered in GB. The DVLA produce statistics on this under table VEH0150 - Vehicles registered for the first time by body type.

Q: Does the modelling for transport include commercial vehicles, HGVs, buses and trains?

A: Our road transport modelling specifically includes all road vehicles, cars, vans, HGVs, motorbikes and buses/coaches. Trains are modelled as part of the industrial/commercial sector modelling.

Q: What are your assumptions behind charging infrastructure for electric vehicles (EVs) and their charging profile?

A: Our assumptions around charging infrastructure are that all new EVs charged in a domestic location would utilise a 7kW charger rather than a 3kW charger. For the charging profile, we used the information from the Low Carbon Networks & Innovation (LCNI) project 'My electric avenue' to determine the diversification of charging at different times during the day and seasons. One of the major factors that influences peak domestic EV charging is how engaged the consumers are. Those most engaged consumers utilise smart charging to move their demand to an off-peak period.

We have also considered non-residential charging this year and used the assumption that this would be opportunistically and part of a journey rather than a journey specifically for charging. For this we have used the road survey data to determine the proportion of vehicles likely to be travelling at peak times; and proportioned the annual demand to determine how much energy would be required at peak time. Further information can be found in our Modelling Methods document at: https://www.nationalgrid.com/uk/publications

Q: Does the total cost of ownership (TCO) assessment of electric vehicles assume a £4,500 grant for each of the 11m new cars?

A: Depending upon the scenarios, the ULEV incentives for purchasing a car will either stop after the currently announced funding dates or continue but only for a short number of years. In none of the scenarios did we envisage this incentive continuing out to 2030.

Q: Does your modelling of EVs include degradation cost? These result from cycling the batteries when these are used to support the Grid.

A: Our underlying assumption is that the cost of vehicle to grid would have to cover any costs incurred as part of its operation or deployment.

Q: The likely vehicle fleet in future looks like it will be largely autonomous, largely electric, and owned by fleets. Will charging mainly happen in large hubs?

A: Currently half of all new car sales are for fleet vehicles and we see that continuing into the future. Currently these fleet purchased vehicles are refuelled by those who operate them and this may continue into the future. In our scenarios we have included a mix of charging, both residential (7 kW) and non-residential (7 kW to 350 kW) in order to cover the range of uses that cars are and will be put to and hence where they are charged. Our stakeholders said that, although vehicles may be autonomous, it does not mean that they are shared; and we have reflected this within our scenarios.

Q: What happens if customers prefer petrol station style ultra-fast charging to home charging. Can the infrastructure cope?

A: As part of FES we make an underlying assumption of sufficient infrastructure for supply and demand requirements, what is described as an intact network (i.e. a network built to be without constraints). This is to ensure that we don't introduce unhelpful feedback loops into the network development process by adding constraints to the fundamental supply and demand balance.

Q: Rather than looking at average grid intensity when deciding when to charge electric vehicles, shouldn't consumers be able to look at the marginal intensity?

A: It is considered that consumers should have sufficient, accurate and timely information available to them, so as to make decisions on their usage of electricity via the market. This should also include the grid intensity, hence National Grid System Operator has been involved in developing a carbon intensity forecast (http://electricityinfo.org/forecast-carbon-intensity/).

Q: How have you taken account of fiscal changes on electric car demand? Fuel duty is much higher than VAT elect (5% domestic). Where do you expect this taxation to move to? Will it be added to energy bills, which could slow EV growth?

A: Whilst we appreciate that new sources of revenues to replace that lost from fuel duty may need to be found as the number of petrol and diesel vehicles falls, we do not explicitly model this (including new taxes being introduced that could slow EV growth).

Q: How would shifting the phase-out of conventional engines to 2030 rather than 2040 affect your FES results?

A: If the aspiration to ban sales of new petrol and diesel vehicles by 2040 was brought forward to 2030, the FES results would change as this 2030 target is not met in any of our current scenarios. Whilst this was not explicitly modelled, it could be expected that electricity demand would rise faster than in the existing scenarios to meet the energy demand currently met by petrol and diesel.

Q: Is National Grid liaising with car manufacturers and EV charging stations providers in order to come up with accurate EV penetration forecasts?

A: We liaise with a wide range of stakeholders in formulating our scenarios. These include car manufacturers, EV charging providers, consumer groups as well as government departments.

Q: How will smart charging and EV charging in response to carbon intensity work together, to avoid increase in charging at peak periods?

A: In our analysis we use the assumption that a commercial market based solution would be utilised to manage smart charging. We would envisage such a solution would financially encourage moving charging away from peak periods. This could include, for example, moving demand to periods of low carbon intensity such as a sunny summer's day when a large amount of solar powered generation is available. The Carbon Intensity API developed by National Grid, in conjunction with other parties, will allow for the development of such smart programs. It can be found at: http://carbonintensity.org.uk/

Q: If smart charging becomes ubiquitous, how will charging levels be controlled? Should it fall to DNOs?

A: In our analysis we used the assumption that a commercial market based solution would be utilised to manage smart charging. This assumption does not preclude networks from providing market signals to effect changes to the timing of smart charging.

Q: How could UK holidaymakers in areas such as Cornwall reasonably charge their electric cars during the summer peak holiday season when they are away from home?

A: We would envisage this as a situation where the individuals would likely charge at a non-residential location such as destination, or forecourt style amongst others that would be available.

Q: Do you think people will charge at home or will the local garage put in a bunch of 500kW chargers? What assumptions underpin each of your scenarios?

A: Based on stakeholder feedback, we have assumed that those with the facility to charge at home, by having off-road parking, will charge at home, as it is likely to be more convenient for them. Those without we assume would charge at non-residential locations such as destination, forecourt or on-street.

Q: Given that consumers don't switch for £300, what incentives are you assuming to get them to alter their charging patterns?

A: Consumers may not switch supplier for £300, however smart charging is a different concept. Switching supplier requires for consumers to compare and to go through the switching process, and many consumers will only switch if they are unhappy with the existing supplier or pricing.

Smart charging is a different idea and it is applied only to EV owners (not the whole population), so the sample is different from the total energy bill payers. EV owners especially in the early years are expected to be the most engaged consumers with low carbon technologies.

In addition, someone who will buy an EV will have to buy also a charger, so inevitably they will start looking for the best deal. In FES we do not specifically look into the incentives, however it is expected that there will be incentives for EV owners and incentives for vehicle manufacturers to facilitate smart charging deployment. Incentives might be in the form of Time of Use Tariffs (TOUTs) and special tariffs for smart charging, discounts or good deal packages for EV owners to buy the smart charger, or in the form of penalties for those that do not avoid peak demands. Two of our four scenarios assume that half-hourly settlements will be introduced in the domestic sector facilitating smart charging.

Q: Do you expect smart charging to be entirely Time of Use based or would it respond to network need (e.g. would people charge at times of high solar & wind generation)?

A: We do not see time of use tariffs as necessarily just static but they can, in conjunction with smart meters, be dynamic allowing engaged consumers to more closely engage with and flex their energy supply and demand. The definition of smart charging includes response to external signals, either these are price signals, carbon signals or network operability signals etc.

Q: 67% have parking, but how many have parking for all the cars of that home? What if there isn't set street parking and people don't want to travel to a charger?

A: We assume that those without off-road parking would charge at one of a number of different non-residential chargers such as destination, on-street or forecourts. For houses with more than one vehicle, we have assumed that each house only has one 7kW charger but that more than one car can be charged in a day if required and that most cars won't need charging every day.

Q: Do you distinguish between hybrid and all electric cars?

A: Yes, we distinguish between plug in hybrids cars and pure battery electric cars within our scenarios; the data on these is within our data workbook.

Q: Do you model electricity demand from rail transport?

A: We model electricity demand from rail transport at a high level only. In our fast decarbonisation scenarios (Community Renewables and Two Degrees) we assume 2.5% demand growth (aiming towards a long-term ambition of electrifying most rail transport, where economic, by 2050). We assume 1.5% growth (the historic rate of demand growth) in our slower decarbonisation scenarios (Steady Progression and Consumer Evolution).

Q: How much of a role does energy efficiency play in your modelling of heat demand?

A: Energy efficiency is a component of our modelling. Government intervention has played a major part in the last decade in reducing heating demand, through providing loft insulation and cavity wall insulation to millions of homes. We note there is significant debate as to how well insulated the GB housing stock should become by 2050 considering the current housing stock, which includes a significant number of low thermally efficient properties. In our highest insulation scenario (Two Degrees and Community Renewables), there is approximately a 48% reduction in space heating demand by 2050, reflecting strong government intervention. Within other scenarios the impact is less.

Q: Should anticipated changes to UK weather patterns drive more demanding design conditions for new building heat systems?

A: If weather patterns drive changes to heating systems at all it would most likely be a small effect - we have not seen any evidence to suggest that current heat systems will be inadequate to meet household needs in the coldest possible day. The main driver of change to heating systems in the coming years would most likely be the need to decarbonise.

Q: Heat options in the scenarios seem very technology-led. How does FES test assumptions on what householders may want? Do you conduct in-depth consumer research?

A: Heat technology projections are built from a model that determines technology uptake based on life-cycle cost, the physical suitability of technology to specific housing types, and a range soft factors that include consideration of customer acceptance such as appeal, installer attitude, awareness and availability, and government policy/incentives.

Q: How important are clear and early decisions / outcomes on heat decarbonisation and policy going to be?

A: Clear policy is very important. All solutions to decarbonise heat require infrastructure upgrades and market changes, which in turn require planning and investment certainty. Making a firm policy decision early will reduce supply chain uncertainty and give the industry the time to develop the most efficient way to transition, with a minimum amount of disruption and cost to consumers.

Q: Is the idea of high heat electrification still credible given the peak electricity grid limitations, the cost and lack of consumer appetite for heat pumps?

A: Heat is a significant challenge which needs to be overcome to meet our 2050 decarbonisation targets.

If consumer heat is not decarbonised, the 2050 carbon targets will be missed.

It is likely that heat will be decarbonised via a range of options and the scenarios are designed to highlight the envelope of possibilities going forwards.

Community Renewables looks at local scale solutions, and uses locally produced electricity to heat well insulated homes. Due to their high coefficient of performance (efficiency) heat pumps are well placed to utilise this energy, the alternative being resistive or storage heat. Technologies such as hybrid heat pumps may help mitigate some of the concerns listed.

Two Degrees highlights the possible use of hydrogen, should a large scale centralised solution be chosen. This would reduce the electrification requirement and could reduce the initial purchase cost for consumers.

Both 2050 compliant scenarios use varying degrees of biofuel, which on its own is not likely to be available in sufficient quantities to heat all GB homes.

Demand: Consumer engagement

Q: What are your assumptions regarding consumer engagement levels?

A: Our modelling of consumer engagement has been drawn in part from the work carried out by Ofgem, which involved direct market research to inform a current position of consumer engagement. The Ofgem consumer engagement survey has been conducted annually since 2014 to track engagement in the domestic energy market following Ofgem's Retail Market Review (RMR). The 2017 research included a new attitude-based segmentation and was conducted with a nationally representative sample of 4,001 energy consumers in Britain.

In our modelling we do use Ofgem's split of consumer segments, however we do not use Ofgem's engagement numbers since these refer to a type of engagement which is different from what we model in FES. We applied engagement trends to each consumer group individually based upon the scenario framework and we assumed different speeds of engagement for each of the six consumer groups (Happy Shoppers, Savvy Searchers, Market Sceptics, Hassle Haters, Anxious Avoiders, Contented Conformers). We also took into consideration 'saturability ceilings' within the sectors for capping the maximum achievable level of engagement for each scenario.

In FES 2018 and following stakeholder feedback, the engagement levels are different for certain smart appliances groups, smart chargers and for consumer price flexibility and they change over time in response to both technology development and changes in attitude, reflecting the landscape of each scenario. Note that despite the adoption of smart appliances, the decrease in peak demand is delayed as it follows learning and adaptation curves i.e. the appliances once purchased are not utilised to their full potential straightaway.

Demand Technologies

Q: How have you selected low carbon technologies in your scenarios and not selected others?

A: We carefully assess all potential new technologies that are publicly available. We use a number of criteria to test whether any given technology should be included within FES. This includes technology maturity, supply chain potential, commercial readiness, and support required, together with consumer and political interest. Each year we reassess the technologies to ensure that we capture innovation and we test this through engagement with stakeholders.

Q: Do you consider vehicle-to-grid (V2G)?

A: We have included V2G in the FES scenarios for the first time this year. V2G could be significant source of future flexibility. There are about 38m million electric vehicles by 2050 in both Community Renewables and Two Degrees, and there are a large number of trials of this technology, offering commercial opportunities. We have assumed that the most engaged segments of society are those most likely to take part in V2G within the scenarios; reflecting both the uptake of electric vehicles and the engagement with smart technologies.

One of the major factors that influences peak domestic EV charging is how engaged consumers are. The most engaged consumers utilise smart charging to move their demand to an off-peak period. In Two Degrees, for example, we see high consumer engagement and a lower proportion of EV charging at peak. Both Smart charging and V2G have the potential to be very important in a mass EV world as it is likely to be a significant factor in the extent to which additional generation capacity and network reinforcements are required across the electricity system, to cater for demand caused by increased numbers of EV chargers.

Q: How do you see the energy market evolving to allow private EV users to benefit from participation in V2G?

A: There are already multiple trials on V2G within the energy market as well as it least one current commercial offering to consumers. Based upon this we would say that the energy market is already evolving to allow private EV users to engage with V2G.

Q: V2G is essentially a form of storage. Why have you chosen to split this out from other types of storage?

A: As a vehicle is primarily purchased for transport and not as a form of electrical storage, the pattern of usage, charging and engagement will be different enough from static storage that they should not be included within static storage. However, our modelling does consider how different forms of flexibility work best alongside each other.

Q: As it gets cheaper, towards 2040/2050 won't battery storage cannibalise V2G?

A: We see V2G as being likely to continue going out to 2050 due to the nature of the primary investment; a vehicle is primarily purchased for transport not for V2G. Also, the price of EV batteries is just as likely to continue to fall in the future.

Q: Why can't EVs decrease peak demand under some scenarios rather than adding to peak demand in all scenarios? With V2G and smart charging, can this be achieved?

A: It is entirely possible that a combination of smart charging and V2G could be used to decrease net peak demand. This is the first year that we have included V2G within the scenarios, and as there is still considerable uncertainty around V2G deployment, we have been conservative with the numbers of users that would engage with it.

Q: Your V2G forecasts seem to have been exacerbated, given that not much innovation happening in that direction. What is your view on that?

A: In this year's scenarios we have been conservative with V2G uptake, limiting it to only the most engaged sections of society. There are a large number of projects around V2G currently underway, or have already been delivered to advance V2G, for example, several InnovateUK projects, projects by UK Power Networks and Western Power Distribution as well as TenneT in the Netherlands. The UK Government is also investing £30m into V2G technology.

Q: What are your assumptions around EV infrastructure to provide V2G, e.g. will there be connections in parking spots?

A: We have been conservative about V2G in this year's FES scenarios; as such we have only assumed a small number off-road charging capable individuals would be engaged with V2G. As part of next year's FES scenarios, we will be seeking to understand the fleet users' opinions regarding V2G, and where applicable include fleet users in V2G.

Q: Will overall energy costs for consumers fall if they are charging cars and feeding electricity back to the grid instead of buying petrol/diesel?

A: This is not an area that has been explicitly modelled as part of our costing work at present. However, as part of the road transport modelling work we have calculated that the total cost of ownership of an EV is likely to be less than a corresponding petrol or diesel car in the 2020s and any additional revenue from vehicle to grid services should further reduce total energy costs for a given energy consumer / EV owner (e.g. compared against use of a petrol or diesel vehicle).

Q: There's consensus that smart charging (and V2G) will be essential for shifting peak load. How do you see EVs participation in balancing services?

A: National Grid's Power Responsive programme considers EV participation in balancing services which can be seen on the website (e.g. Power Responsive - how smart charging can help and in the Power Responsive Annual Report)

Q: The chart showing smart charging had V2G at the winter teatime peak roughly match EV charging in 2040. If this is the case, why is peak demand increasing sharply?

A: The chart shown was for illustration only. What we can say is that we applied conservative estimates of V2G engagement, this being the first year we included it and there being large uncertainty from the car manufacturers over whether to allow V2G.

Q: Do you have profiles for heat pump and EV usage?

A: Yes, our profiles are informed by data from 'Low Carbon Network' projects, which were funded by Ofgem. The 'Customer Led Network Revolution' project library contains a wealth of information on different innovation project trials: http://www.networkrevolution.co.uk/resources/project-library/

Searching for 'Electric Vehicles' or 'Heat Pump' will find the following datasets, as well as a number of reports and summaries on trial design and findings. Data is also available for residential solar panels, micro Combined Heat and Power (CHP), and DSR trials.

CLNR-L078 Dataset TC6: Enhanced Profiling of Domestic Customers with Electric Vehicles CLNR-L075 Dataset TC3: Enhanced Profiling of Domestic Customers with Air Source Heat Pumps

Additional information is available from the 'My Electric Avenue', which trialled over 100 Nissan Leafs for 18 months: http://myelectricavenue.info/

Q: Why are there not more hybrid heat pumps in Community Renewables (CR) given the ability to use local peak clean electricity when available and the gas grid for peaks?

A: There are 3.5 million hybrid heat pumps in CR which is more than 10% of all heat appliance installations. Hybrids are net positive carbon emitters and this limits the number of hybrids in a scenario for a given carbon budget. In CR, consumers are empowered to choose among alternative heating

technologies and the whole system benefits of hybrids notwithstanding, hybrids still face stiff competition from cheap, high efficiency gas boilers.

Q: Do you include fuel cells in EV numbers?

A: Vehicles powered by hydrogen fuel cells are included in the road transport numbers in this year's FES for multiple different types of vehicle (Cars, Vans, Buses and HGVs).

Q: How do you account for demand side response (DSR) in FES?

A: In FES we look into total DSR (i.e. usage shift, micro generation and micro storage) and we also explicitly model pure load reduction DSR which is when consumer has shifted their usage. Only pure DSR is used to reduce FES peak demand and this happens because in FES we are interested in the underlying demand. We do not include cases where a consumer has switched to another power source – such as a generator or battery storage. This is not a demand shift as their demand is still the same; it is just being sourced differently. This figure would be captured in the supply side and, if we were to include on the demand side, we would end up double counting the true generation that is available. We only account for turn down demand DSR and we do not look into DSR in summer.

In FES we do not include I&C DSR within our definition of peak (our definition is an 'unrestricted' one), but we do incorporate residential demand shift because of time of use tariffs. Residential demand shift is considered to be behavioural change and therefore less responsive to real time signals.

Q: How do FES projections of demand side response link to Power Responsive report?

A: As part of our internal stakeholder engagement we have shared our outputs and analysis with the Power Responsive team and this engagement is ongoing. We have consulted with Power Responsive on trends and forecasting and they have shared useful insights and information with us. The difference in demand side response approach between FES and Power Responsive report is that in FES we only report demand side response at winter peak days. We do not report capacity as in the Power Responsive report. The total demand side response numbers, which can be found in the data workbook, tab ED10, reflect the maximum real demand reduction (or maximum observed Customer Demand Management) that we see in the transmission network at a winter peak day and time. This is a different number from what is reported in Power Responsive as tendered and accepted MW capacities of Demand Side Flexibility (DSF).

Q: What is the role and scale of demand side response (DSR) in the Community Renewables and Two Degrees scenarios?

A: In both Community Renewables (CR) and Two Degrees (TD) DSR is seen as another source of flexibility. The role of DSR is expected to grow in the future in these scenarios, when more flexibility is required and consumers become more familiar with DSR technologies. DSR from load reduction only (e.g. as opposed to back-up generation) is in the range of 3.6 to 3.9 GW for CR and TD by 2050. More details can be found on the Data Workbook (tab 4.7 and ED10) at: http://fes.nationalgrid.com/fes-document/

Q: Do you expect smart metering to respond to levels of wind / solar generation?

A: Smart metering on its own cannot respond to external signals. It is the smart appliance that will be communications-enabled and able to respond automatically to price and/or other signals by modulating its electricity consumption. These changes to consumption patterns are what we call the 'flexibility' of the smart appliance. The smart appliance could respond to levels of wind/solar generation if that is deemed appropriate for the user's purposes. This topic is touched upon in the FES 2018 spotlight on Hybrid Heat Pumps on p71 of the main FES document.

Q: Why could shared vehicles increase energy demand?

A: Currently privately owned cars, including EVs, are parked on average 95% of the time. Within the scenarios, we have used shared autonomous vehicles, where an EV does not require a driver to move from place to place, and so can be easily utilised by multiple people. This increases the utilisation of the vehicle, and thus the miles and energy consumed per vehicle.

As an example, if person A uses the autonomous vehicle to travel to work, rather than leave the vehicle parked all day it is then sent to be used by person B. When person A needs the vehicle later in the day they would then call it to them.

Q: Have you considered hybrid heating in your scenarios?

A: Hybrid heating and its effects are considered within the scenarios. Hybrid gas boiler & heat pumps are among the low carbon heating technologies modelled. This year hybrids feature in all of our scenarios and are a prominent feature of Two Degrees and Community Renewables. They offer green heating throughout most of the year, running primarily on a heat pump, and then switch to gas for the cold peak times. Projects such as Project Freedom are furthering the industry's understanding of potential decarbonised heating solutions and we continue to monitor progress.

Q: Is hydrogen a plausible option in a domestic environment considering its safety issues?

A: Hydrogen is considered a plausible option. However, research is ongoing about how to tackle a number of engineering challenges as well as formulating appropriate safety guidelines for a large scale rollout.

Q: Does hydrogen heating need a full replacement of the gas infrastructure, e.g. pipes and boilers, and the creation of large generation plants? If so, isn't that too expensive?

A: Hydrogen heating will not need a wholesale replacement of the gas infrastructure. One of the attractions of hydrogen heating is the potential for repurposing of the existing infrastructure both at the transmission and distribution levels. However, some new infrastructure will be required (e.g. steam methane reformers and CCUS plant).

Q: Do you see a role for biomass heating?

A: Biomass combined heat and power plays a significant role in Consumer Renewables scenario to decarbonise heating in the industrial & commercial sector. Biomass could also play a role in residential heating via District Heating schemes as a sole fuel source or as fuel backup to waste heat. However, we are slightly cautious with the extent of its use as explained in relation to electricity generation on p104 of the main FES document.

Q: What role could growth in peer-to-peer platforms play in better managing supply / demand?

A: In April 2018 the first UK physical trade of energy took place using blockchain and there is regulatory support for future development. Such trading arrangements will become particularly important for the development of such arrangements as vehicle-to-grid technology. We see such developments being particularly strong in the more decentralised scenarios of Consumer Evolution and Community Renewables. The development of localised trading will mean many more consumers will evolve into prosumers.

Supply

Q: Where can I find information on your projections for generation capacity?

A: In the Data Workbook, downloadable with the main document:

- Tab ES1, contains capacity figures (MW) for transmission and non-transmission connected generation (contains micro-generation), as well as totals.
- Tab ES1, also contains annual output figures (GWh) by the categories described above, as well as totals.

Q: Are network constraints (such as thermal constraints, or fault current constraints) taken into consideration when calculating the amount of generation that is going to connect to either the transmission or distribution network?

A: Our modelling is built up from historic network performance, but we don't take into account current operational unavailability. One of the roles of the scenarios is to illustrate and highlight potential future need for change on the electricity system. The impact on networks is assessed in the other System Operator documents, including System Operability Framework (SOF), Electricity Ten Year Statement (ETYS) and Network Options Assessment (NOA), see https://www.nationalgrid.com/uk/publications

Q: How do you ensure that three hours of Loss of Load Expectation is met? Which modelling are you using?

A: We have included more detail on how we ensure the scenarios meet the 3 hours loss of load expectation in our Modelling Methods Document. This builds on our extensive analysis in this area as part of our EMR Delivery Body work for the Capacity Market, which is published in the Electricity Capacity Report every year.

Q: For gas, there is the 1 in 20 security standard. For electricity, should there be a "windless 10 days in January" standard?

A: All of our scenarios are consistent with the Government's electricity security of supply reliability standard of 3 hours loss of load expectation per year. For more information, please see our Modelling Methods document.

Q: What do you mean by 'local' (i.e. 65% of generation will be 'local')? Do you mean connected to the distribution network?

A: For generation, decentralisation relates to where capacity is located on the network. We assume that generation described as 'decentralised' or 'local' is located on the distribution networks or on the consuming site.

Q: Do you have any information as to the mix of technologies by distribution area (e.g. what percentage of microgeneration is solar PV/wind/gas in each area per scenario)?

A: More regional information in relation to the Future Energy Scenarios is provided on the FES website under the heading "Regional breakdown of FES data" - http://fes.nationalgrid.com/fes-document

Q: What's your view on renewable uptake in a post subsidy world? If government policy continues to not support onshore wind and solar, what are the implications?

A: We have already seen slower growth since the end of the Renewable Obligation. For example, solar growth has slowed considerably. We anticipate subsidy free renewables as costs continue to fall. For solar we anticipate that subsidy free in the early 2020s (behind the meter), mid 2020s (large sites with power purchase agreement) and by 2030 (large, standalone) is possible under the right circumstances.

Q: There is plenty of talk of subsidy free renewables. Should the hidden subsidies to the fossil fuel sector also be reduced to zero?

A: In our Future Energy Scenarios, we explore a range of technology mixes as there remains considerable uncertainty associated with technology cost reductions, political and public support. We also explore different energy worlds where differing levels of support are offered to renewable and fossil fuel technologies; however, we make no recommendations about whether any kind of subsidy should be applied or removed as this is not the purpose of FES. Where we procure services (for example Enhanced Frequency Response) we are technology agnostic and we support a level playing field.

Q: What assumptions have you made around onshore wind repowering in your scenarios?

A: We have used our new scenario framework to update our assumption here. We now assume that sites will generally repower (subject to any planning permissions) either as like for like capacity or with a larger capacity if the grid connection allows. We welcome feedback on this, and in particular whether sites will repower with larger turbines.

Q: In the world where the French nuclear fleet is in decline, what happens when there is a blocked weather pattern? Are interconnectors actually providing flexibility?

A: All our scenarios are consistent with the electricity security of supply reliability standard of 3 hours' loss of load expectation per year. Our modelling covers a wide range of credible scenarios, including different weather conditions in both GB and the rest of Europe. This results in situations with interconnectors importing to GB and situations when they are exporting from GB, depending on market prices.

Q: GB currently exports electricity to France during high winter demand due to higher French temperature sensitivity. How is this reflected in the scenarios?

A: As above, all our scenarios are consistent with the electricity security of supply reliability standard of 3 hours' loss of load expectation per year. Our modelling covers a wide range of credible scenarios, including different weather conditions in both GB and the rest of Europe. This results in situations with interconnectors importing to GB and situations when they are exporting from GB, depending on market prices.

Q: Interconnectors can be a source of flexibility. Should we rely on them for capacity/security of supply as well?

A: As above, all our scenarios are consistent with the electricity security of supply reliability standard of 3 hours' loss of load expectation per year. This is delivered through the GB Capacity Market, in which interconnectors are allowed to participate. Their contribution to security of supply is factored into our analysis.

Q: If high pressure weather occurs in winter, so there is both little wind/sun and high demand for long periods, how might GB power grid cope?

A: As above, all our scenarios are consistent with the electricity security of supply reliability standard of 3 hours' loss of load expectation per year.

Q: National Grid has previously suggested the market for frequency response will be ca. 2GW. How do the storage and interconnector assumptions in FES fit with this? Will frequency response need to be higher?

A: Our scenarios are the starting point for a number of other activities within the business. These activities include assessing operability and the need for balancing services. The outputs of this work will be published later in other System Operator publications such as the System Operability Framework (SOF).

Q: When you look at installed capacity do you use derated figures to reflect the load factor, e.g. different factors for solar PV and combined cycle gas turbine (CCGT)?

A: All capacities are de-rated when their contribution to meeting peak demand is modelled (noting that PV is negligible at this point in time). In terms of annual contributions, load factors are generated by our dispatch modelling. However, when 'installed capacity' is quoted this is Transmission Entry Capacity (TEC) (i.e. the contracted maximum capacity of the unit) and doesn't include any de-rating or load factor.

Q: In the "old days", we were told that large power stations were cost efficient. Have economics changed given the forecasted decentralised system?

A: Our scenarios consider the development of a decentralised system to reflect potential changes to the system as the country aims to decarbonise. This covers higher levels of generation connected to distributed systems. It includes technologies such as solar, batteries and small thermal peaking plant. Small-scale renewable generation has recently been brought forward by subsidies such as the Renewable Obligation and falling costs could see deployment on a subsidy-free basis. In addition, whilst there is some uncertainty on how the impact of reducing embedded benefits will impact further delivery of peaking plant that has been cleared in recent Capacity Market auctions, Capacity Market trends have been reflected in our scenarios. The energy landscape, including some of its economics are changing and it's important that the System Operator plans for a credible range of outcomes.

Q: Do you see Hinckley Point C being built at a strike price of £92.50/MWh for 35 years when offshore wind is now at £57.50/MWh for 15 years and falling?

A: We don't publish the details of specific projects that we have included in FES. However, our scenarios consider the need for both nuclear and offshore wind to help meet decarbonisation targets.

Q: Should there be a 'big nuclear' scenario when the UK builds, say, five Hinkley-sized plants by 2050?

A: Our scenarios cover a range of projections for nuclear capacity in GB by 2050, with a range of 9GW to 18.5 GW by 2050.

Q: Are the 15 year contracts coming out of the Capacity Market consistent with the FES scenarios?

A: Yes. We make use of the Capacity Market report and registers when developing our scenarios. Sites with contracts are typically included in our scenarios although we do consider risks of non-delivery where appropriate.

Q: Do you think there's a need and room for a renewable Capacity Market (in addition to/to replace the current Capacity Market)?

A: At the moment, renewable capacity in GB has been delivered through a number of different schemes including feed-in-tariffs, the Renewables Obligation and contracts for difference. Capacity without this support is eligible to participate in the current capacity market. Our scenarios take account of these factors. Of course, this may change in future and the participation of renewables in the Capacity Market will be considered as part of the upcoming review, and any changes will be reflected in our analysis.

Q: Are your Carbon Capture Storage and Utilisation (CCUS) assumptions based on analysis of the technology or are they driven by the need, assuming the technology will just happen?

A: There is some uncertainty around CCUS as it is an emerging technology and we have included it in two of our scenarios this year. CCUS is included in both Two Degrees and Steady Progression. In Two Degrees, we assume it is deployed from 2030 onwards and is linked to the production of hydrogen for heat via steam methane reforming. In Steady Progression, CCUS isn't deployed until 2039. Our projections make allowances that technology and financing will need to be developed before it can be deployed commercially.

Q: Is the take-up of CCUS in your scenarios realistic, given the technological and funding challenges?

A: There is some uncertainty around CCUS as it is an emerging technology and we have included it in two of our scenarios this year. CCUS is included in both Two Degrees and Steady Progression. In Two Degrees, we assume it is deployed from 2030 onwards and is linked to the production of hydrogen for heat via steam methane reforming. In Steady Progression, CCUS isn't deployed until 2039 and there is no hydrogen creation from steam methane reforming. Our projections make allowances that technology and financing will need to be developed before it can be deployed commercially. However, without CCUS, 2050 compliance becomes significantly more challenging and the sector is currently seeing increased levels of interest and funding.

Q: Does tidal energy have a future role to play when the UK seems unwilling to be a first mover to develop the technology?

A: Our FES 2018 scenarios cover a range of possible outcomes for the future of tidal technology. We currently have 27MW of installed tidal capacity in Great Britain. The scenarios cover a range of between 69MW and 6,083MW by 2050 taking into account projects that already have consent granted, those awaiting consent and those still in the scoping phases. We believe that the range we have provided is consistent with our framework assumptions, and is credible, given the level of uncertainty

around the future of tidal technology for electricity generation. We will, of course keep this under review for future editions of FES, not least considering recent developments in the sector.

Q: What assumptions have been made in FES about the maximum non-synchronous generation the grid can handle?

A: In our FES analysis, we only consider an energy balance and don't consider network or operability constraints. The FES is the starting point for a number of System Operator activities including network development and operability. These assumptions are tested in more detail and will be published as part of our other System Operator publications (e.g. Electricity Ten Year Statement, Network Options Assessment, System Operability Framework).

Q: Does National Grid have a view as to the appropriate mix of flexibility mechanisms (grid upgrade, storage, DSM) at a distribution level as generation/demand changes?

A: Our scenarios are intended to consider a range of credible projections for different technologies. This covers both transmission and distribution-level connections. This is informed by extensive stakeholder engagement with industry experts and our own analysis. Our scenarios highlight the need for flexibility. The FES is the starting point for a number of System Operator activities including network development and operability. These assumptions are tested in more detail and will be published as part of our other System Operator publications (e.g. Electricity Ten Year Statement, Network Options Assessment, System Operability Framework).

Q: Do you distinguish between within day storage and seasonal storage? In winter, there can be very little sun and on occasions little wind? What happens under those conditions?

A: In our modelling, we take account of the different types of storage in terms of their duration (i.e. how long they can charge / discharge for at a given rate). This is important in relation to modelling of security of supply as it helps to determine how the different technologies should be de-rated (similar to treatment in the Capacity Market). This security of supply modelling takes into account the expected behaviour of wind (and solar) at times of peak demand.

Q: Can you clarify what you consider large storage?

A: On the assumption that this question relates to the reference to "large-scale storage" in the morning presentation of the FES 2018 Conference, this is taken to mean non-battery storage such as pumped hydro, compressed air and liquid air storage. Transmission-scale batteries are also considered in the modelling.

Q: What is the view on large scale storage? The analysis indicates small growth. Is this based on currently planned projects? Will interconnectors supersede the need?

A: We consider a range of large scale storage capacity across our scenarios, with the majority of the growth considered in our centralised scenarios. In FES, our assumptions are informed by both known projects and projects that we may not yet know about. We have also modelled how different sources of flexibility interact and potentially cannibalise each other, which is part of the reason there is no interconnector growth after 2030.

Q: How does National Grid see the use of battery storage solutions for investment deferral, for North-South lines for instance?

A: Our scenarios are the starting point for a number of other activities within the business. These activities include assessing the need to develop the network. This analysis will be conducted later this year and published via the Electricity Ten Year Statement and the Network Options Assessment.

Q: What replaces the seasonal hydrocarbon battery?

A: Assuming that the "hydrocarbon battery" relates to the existing fleet of coal and gas generators, the extent to which these are replaced varies across the scenarios. However, to a greater or lesser degree dependent on the speed of decarbonisation axis, flexibility is increasingly provided by interconnectors, storage and, in the later years of the scenarios, vehicle-to-grid technology.

Q: How do you see seasonal storage of electricity developing (i.e. not EVs but new large-scale technology)?

A: There is growth in storage across all of the scenarios, especially Community Renewables, and this varies by technology type and associated duration (i.e. how long they can charge / discharge for at a given rate). However, following stakeholder feedback, large volumes of "seasonal storage" have not been explicitly modelled. The development of hydrogen offers potential in this area which may benefit from further investigation.

Q: Batteries are important in all scenarios. Do you take account of the raw materials required for them in terms of sustainability and scale?

A: Our modelling in relation to meeting the 2050 carbon targets doesn't take into account the sustainability impact of the raw materials required to produce batteries (in a similar manner to how other upstream non-GB emissions are treated). However, the availability of the raw materials to meet demand for batteries (both current and future technologies) is considered as part of the storage modelling.

Q: Do you consider the evolution of the energy mix to estimate the derating of storage across the years? Does this inform your deployment projections?

A: Different de-rating factors, largely linked to duration (i.e. how long they can charge / discharge for at a given rate), are considered as part of the storage modelling carried out as part of FES and our assumptions in this area impact the future energy mix and change across the different years in the four scenarios.

Q: Why do you use generic imports for gas supplies?

A: The background and our thinking on the UK's gas supply sources are described in chapter 5 in the main FES document. In summary, we build our gas supply scenarios by assessing the likelihood that various supply types come to GB. For example, UK Continental Shelf, shale or green gas (biogas or bio-substitute natural gas) are added to our supply sources first as they are indigenous. This is followed by Norwegian gas, as some fields are directly connected to import terminals in GB, and minimum levels of liquefied natural gas (LNG) are added as some LNG must flow due to boil-off requirements.

For some years, our scenarios have included specific volumes of imported LNG and continental gas, as well as a volume of 'Generic Import', which could be LNG or continental gas, or a mixture. This approach effectively provides ranges for LNG and continental gas imports in each scenario. Predicting LNG flows in the world market is challenging, and you have told us that our approach is a sensible way of dealing with the uncertainty.

Q: What do your scenarios say on gas import dependency?

A: This year's Future Energy Scenarios highlight various levels of gas import dependency across the different scenarios. Import dependency is ~51% for 2017, but this increases to ~89% by 2050 in Two degrees as the only indigenous gas supply by 2050 is green gas. In contrast, import dependency in Consumer Evolution decreases to 46% by 2050 as shale gas and green gas provide over 35bcm/yr by 2050. The other scenarios range between these two.

Q: If your forecasts on the decline of the UKCS & Norway are correct, where is the gas going to be sourced from, assuming rapidly increasing imports?

A: Gas supply in GB is varied with supplies coming from a wide range of sources. In all the scenarios, supplies from the UKCS and Norway decline, but supplies from other global sources such as LNG and continental Europe (via the Interconnectors) increase.

Q: Should we be concerned about the potential high level of gas import dependency in the scenarios? Is additional gas storage required?

A: The National Transmission System (NTS) delivers a wide range of gas supply patterns. It is important that this continues as supplies from the UKCS and Norway decline and are replaced by more flexible sources of supply such as LNG and continental imports. Through FES we undertake an infrastructure test known as the N-1 test, which analysis whether gas demand can be met with the largest piece of infrastructure unavailable. All scenarios show we can pass the N-1 test. This test assumes that the GB gas market will deliver the gas volumes to the NTS. Gas storage is included within the N-1 test.

Q: Do you expect more gas deficit warnings to occur in the future and if so why and what can be done?

A: The GDW issued in March was due to a number of features outside our control, including failure of upstream components. In our scenarios, we believe that there will be enough gas to meet peak demand. In our Winter Consultation, we announced that we will consult with the industry on the working of the GDW and Margins Notice mechanism through the Transmission Workgroup.

Q: Do you forecast the closure of St Fergus?

A: With the decline in the UKCS, there will inevitably be some effect on the existing gas supply infrastructure. However, within the Future Energy Scenarios, we do not analyse the effects of the changing gas supply patterns upon specific gas infrastructure.

Q: How secure is our gas supply following the withdrawal of Rough and Hole House storage?

A: Gas supply in GB benefits from a diverse range of supplies - both from indigenous gas supply and gas from imports. In 3 out of the 4 scenarios, imported gas will become even more important. The wide range of different gas supplies is expected to ensure GB gas security.

Q: How secure is our gas supply following the withdrawal of Rough and Hole House storage?

A: Gas supply in GB benefits from a diverse range of supplies - both from indigenous gas supply and gas from imports. In 3 out of the 4 scenarios, imported gas will become even more important. The wide range of different gas supplies is expected to ensure GB gas security.

Q: As system flows change, will there still be enough within day gas flexibility?

A: We make the point in a spotlight that a gas network with lower total flow is not necessarily easier to manage. It will be important that we make the case for adequate investment in the network to allow us to deal with changing flow patterns.

Network and System Impacts

Q: What are the grid development implications of each of these scenarios?

A: We publish a number of documents which illustrate the potential development of the gas and electricity transmission systems, including (see: https://www.nationalgrid.com/uk/publications):

- Gas Ten Year Statement (GTYS)
- System Operability Framework (SOF)
- System Needs and Products Strategy (SNAPS)
- Network Options Assessment (NOA)
- Electricity Ten Year Statement (ETYS)

Q: Your scenarios point to a continuation of north to south electricity flows. Is this going to expedite the development of Eastern HVDC1 and/or onshore reinforcement?

A: The scenarios highlight that, with a more decentralised system, the power flows will change in all directions. Our scenarios are the starting point for a number of other activities within the business. These activities include assessing the need to develop the network. This analysis will be conducted later this year and published via the Electricity Ten Year Statement and the Network Options Assessment.

Costings

Q: Do the scenarios attempt to consider the total cost in reaching the 2050 target? Does your costing work include capital costs?

A: We are deriving costs for all four scenarios, accounting for those that achieve 2050 compliance and those that don't. Our focus is on the cost of energy production, transportation and end consumer technology costs.

Q: Has there been any forecasting done to estimate the cost of meeting the scenarios for heat pumps?

A: As explained above, we are deriving costs for all four scenarios. Our focus is on the cost of energy production, transportation and end consumer technology costs, including the deployment of heat pumps.

Q: What are the differences in levelised cost of electricity (LCOE) across the different scenarios?

A: We are undertaking the task of costing the Future Energy Scenarios. As stated in the FES 2018 document, this is at an early stage. It is our intention to continue our analysis during the summer and autumn before considering our approach to stakeholder engagement.

Q: Do the scenarios allow long term price curves to be calculated?

A: One area where this is pertinent is our electricity market modelling. We use BID3 to model the wholesale electricity market in GB and the rest of Europe. This assumes costs for fuel and carbon, which are published in our data workbook. BID3 calculates the generation that is used to meet demand at lowest cost, effectively determining the merit order and the wholesale electricity price for each period modelled. At the moment we don't publish this information. However, as we develop more experience with BID3, we continually revise the information that we publish, include future price projections.

Q: Do you include the effect of wholesale price cannibalisation when assessing how much onshore wind capacity can be delivered without subsidies? Who is going to pay for the new renewables when they drive the power price down?

A: Our whole system model looks at generation dispatch and wholesale price and includes situations where the volume of renewables (in favourable weather conditions) can lead to the wholesale price being pushed down. Within our detailed modelling, we then look into more detail how flexible technologies (such as battery storage) can be used to manage periods of excess supply. This is covered within the FES document. Flexible technologies are an enabler for increased levels of renewable capacities however there may be some cases where further government support is required to promote growth in renewables.

Q: Do your scenarios consider affordability to the consumer? Interventions such as Energy Intensive Industry (EII) exemption indicate stress on the market.

A: The focus of the costing work is to provide an indication of the costs of each Future Energy Scenario world. Affordability is a very important aspect associated with costs. However, affordability also links to many other aspects such as the financial markets, energy policy in general (taxation, incentives & obligations for example), and development of existing new business models. Our costing work is not intending to explore these issues at this stage.

Q: Some of the scenarios result in large reduction in gas required - to nearly nothing. Do the cost of scenarios take into account asset stranding, job losses etc?

A: Our costing work is not focusing on the possible impacts of stranded assets or impacts on the wider economy through impacts on business. Our FES work will hopefully provide additional information for which such considerations could be developed by the industry.

Version control

Version number	Date of update	Description of update
1.0	12/07/2018	First upload for FES 2018 launch on 12 July 2018
2.0	09/08/2018	Updated version including Q&As since FES 2018 launch
3.0	03/09/2018	Update to cover additional Q&As since the FES 2018 launch

For any queries, please contact us at: fes@nationalgrid.com