nationalgridESO

FES 2019

Questions and Answers

August 2019

Contents

Our *Questions and Answers* 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

This document seeks to answer the main questions we receive as we publish FES. As with our other FES documents we welcome your feedback, please contact us at: fes@nationalgrid.com

Questions and Answers

General

Please can you clarify the year definition for data tables.
Fiscal years refers to April to March. All other tables are January – December.

Electricity Demand

Where is all the data you used to publish?
Following customer feedback, we have consolidated the data in to a smaller number of sortable worksheets as follows.
ED1: Electricity demand data - Demand by sector and component.
ED2: Electricity demand data (notes) - "Components" may be added together to form totals. "Model" data is information prior to scaling/modification before being included in other totals. "Assumptions" are assumptions in our modelling.
ED3: Heat and gas demand data
ED4 Heat and gas demand data definitions
ED5: Transport - Number of road vehicles and associated energy demands. Note we've had feedback saying this table is confusing so we're working on making it more explicit.
This puts all the relevant information into fewer sheets. The charts shown in FES remain as separate tabs.

Why does electricity demand increase in Steady Progression?
There is some electrification, but far less energy efficiency than in other scenarios.

Why is there an increase in 1-in-20 gas demand in Steady Progression and Consumer Evolution?
There are three main components that are contributing to the increase: gas for power generation, LDZ demand and exports to Ireland. The biggest increase is in gas for power generation, partly because of observing the highest gas demand for gas NTS connected power generation during winter 18/19 and partly because of a slight change in our assumptions contributing to a peak gas demand for power generation. LDZ demand has increased for many reasons: improvements in our modelling of distribution connected gas-fired flexible generation; reductions in our residential thermal efficiency improvement assumptions; pushing back electrification of domestic and commercial heating; and a slight re-allocation of actual historic non-daily metered (NDM) demand towards the weather sensitive residential load band, because of new reconciliation data. Ireland experienced a very high gas demand on the 1 March 2018 and so GNI have subsequently increased their peak gas demand assessment, which increases exports to Ireland from GB.

Why is there no hydrogen used for heating in Community Renewables?
No CCUS in CR and so no hydrogen from SMR/ATR. *There is hydrogen from electrolysis used in transport.*

Are losses separately published?
This year we have consolidated unpublished energy demand data in tables ED1-ED5.

Could you explain how your regional breakdown of FES works – is it simply a top-down application on the national projections to a more local baseline?
For demand, it is a top down application using local data, we are looking to develop more regional analysis in future FES documents. More information is available in the modelling methodology document.

Heat

Why do you need energy efficiency improvements in TD if there is hydrogen?
We have brought this down from FES 2018. However, there are still Heat Pumps and hybrids in TD and, also, there is a benefit in improving thermal insulation as it reduces the amount of H2 required (and thereby reduced fuel costs and carbon emissions).

What is the fuel source of the hybrids on bar chart slide?
Annually, 80% of heat demand would be met by the heat pump component of the hybrid system and 20% by the gas boiler. These percentages would however vary from day to day. We assume the gas boiler would meet 100% of demand on the coldest days of the year.

How realistic is the diverse range of technologies applied in TD and CR? Is this dictated by the regional aspect?
Yes - this is dictated to a degree by regional drivers. For instance, in TD, hydrogen would be more competitive in Scotland and in Northern and Midland LDZs whereas hybrids might be more suitable in Wales and Southern regions. Technology diversity has also been created by an optimisation process which considers the technology costs, customer acceptance and level of local government and community support.

There are a lot of HPs as well as EVs in CR... What is the impact on the DNO?
This is linked to time-shifting of electricity demand which we cover in transport slides. However, bigger point is that the scenarios look at underlying energy demand which is unconstrained by network issues (both Tx and DNO). We don't model DNO impacts.

What technology supplies heat for district heating (especially in Community Renewables and Two Degrees) and what is the driver to install district heating given distribution losses?
A range of technologies are modelled as heat sources for district heat, with the proportion of each adjusted to be consistent with scenario frameworks. The main driver for district heat is the relative ease with which their power/fuel source can be switched from high carbon to low carbon with little or no disruption to the end consumer. New materials and digitalisation are helping to minimise losses in networks and this trend is likely to continue.

Gas CHP
Air source heat pump
Ground Source heat pump
Water source heat pump
Biomass boiler
Deep geothermal
Energy from waste
Biomass
Industrial waste heat

Why have numbers of ground source heat pumps (GSHPs) significantly decreased in this year's FES compared to 2018?
This is a result of the analysis of relative competitiveness of GSHPs versus other alternatives in terms of costs and ease of installation in existing domestic housing stock. GSHPs would find widespread applications in the commercial sector as well as in district heat networks.

How much have you reduced improvements to domestic thermal efficiency in this year's FES compared to 2018, and what are the reasons and evidence behind this?
The range of domestic thermal efficiency improvement assumptions have reduced from 20 – 35% in *FES 2018*, to 9 – 26% in *FES 2019*. The changes have been made by considering stakeholder feedback and benchmarking against recent modelling by CCC and BEIS.

[[1] https://www.nic.org.uk/wp-content/uploads/Element-Energy-and-E4techCost-analysis-of-future-heat-infrastructure-Final.pdf
[1] https://www.theccc.org.uk/wp-content/uploads/2013/12/Review-of-potential-for-carbon-savings-from-residential-energy-efficiency-Final-report-A-160114.pdf
[1] https://www.theccc.org.uk/wp-content/uploads/2018/09/Imperial-College-2018-Analysis-of-Alternative-UK-Heat-Decarbonisation-Pathways-Executive-Summary.pdf
[1] https://www.gov.scot/publications/energy-efficient-scotland-route-map/pages/2/].

Is insulation improvement fairly linear, or does it mainly occur towards the start of the timeframe?
The improvements are faster in the early years and then settles into a constant rate towards the end.

Can you explain more about regional approaches?
Our current regional approach is driven mainly by the growth of hydrogen use in the scenarios and assumptions around policy differences between regions. For example, Scottish, Northern, and Midland regions would have higher uptake rates for hydrogen either because of higher industrial concentrations or because of proximity to H2 and CCC infrastructure. Wales and Southern regions would favour more electrification or hybrid systems. Where hydrogen does not feature prominently in a scenario, regional differences are less pronounced. We are always developing our approach to regional modelling of decarbonisation and as part of this an NIA project has recently been approved to explore this in more detail.

Do you envisage hybrid heat pumps running on hydrogen?
Yes, we have considered hydrogen/electric hybrid systems in our Net Zero sensitivity

What EPC rating is assumed to make heat pumps efficient?
EPC band C or better is a benchmark we've adopted. However, we have found EPC to be a problematic measure of efficiency and have only used it indirectly in our modelling

Is all hydrogen produced by SMR? Does electrolysis have a role?
No. Both SMR and electrolysis are used to produce hydrogen in the scenarios. Electrolysis plays a significant role, accounting for ~ 40TWh of hydrogen production in Two Degrees and Community Renewables scenarios

What efficiency difference between heat pumps & boilers has been used? Does this consider how the electricity is produced and losses in transportation?
We have used heat pump coefficient of performance ranging between 2.8 today and 3.8 by 2050. Boiler efficiency are lower ranging between 0.84 today to 0.96 by 2050. These are behind the meter efficiencies and do not account for transportation losses (shrinkage) for electricity and gas. These are considered elsewhere in the energy supply analysis.

How does FES consider industrial heat decarbonisation?
Decarbonisation of the industrial sector would run in tandem with heat decarbonisation in the domestic and commercial sectors albeit with different combination of technologies. In the industrial sector decarbonisation, would be achieved mainly by a mix of biomass, green gases (including hydrogen) and electrification, as well as energy efficiency improvements.

Has there been any discussion with Ofgem or BEIS from the ESO on the policy that will be required on heat to meet the current 2050 targets, never mind net zero?
We engage extensively with Ofgem and BEIS throughout FES development process.

For the Community Renewables scenario, the cumulative number of "District Heat" installations was 446,517 for 2018. This seems very high for a District Heating scheme which I define as "the distribution of heat from a central source of production to multiple

buildings or sites". Does this include small communal heat networks, for example, distribution of heat from a central source to multiple dwellings in a single building?
On the District Heat installs, the 446,517 number represents the number of domestic customers/dwellings on district heat networks. The number of networks would be much lower than this number, approximately 14,000 as you've highlighted.

Transport

Is the late peak assuming a lot of smart charging? What is the source of the data?
Data is from charging providers. This is part of the NIA project.
It includes a lot of dumb chargers (*but, if there is smart charging behaviour in the dataset, this can't be separated out unfortunately*).

Do we have the demographics of EV users here as this could influence assumptions?
No, but we have recently seen the results of a study by the energy system catapult and they saw similar results despite targeting non-early adopters.

What are the VtG assumptions?
It varies across the scenarios and is linked to engagement. CR has the most.

Is H2 in CR only used in transport?
Yes - transport only? Need to be clear on this (no networked H2 in CR).

How quickly do you expect EV roll-out to take place, how smooth it will be and do you see forecourt owners deciding not to bother and range anxiety switching to ICE?
We did petrol / diesel as a counter-factual in the analysis and so didn't specifically model a no-petrol scenario. Good idea to model this.

What are your assumptions about rail transport?
In FES, we assume that rail does get further electrified. This is different across the scenarios. We haven't modelled hydrogen trains at this stage although we have spoken to Network Rail about this.

What about freight vs passenger?
This is something that we don't explicitly model but will be looking at.

In relation to different charging types, what is your thinking around links between the NIA study and the scenarios?
We used the axes in the analysis. In centralised worlds, there is more public charging and work charging. Particularly in TD there is the concept of charging hubs. However, in CR and CE there is much more local / home parking. This is not only off-road parking but also dedicated on-road parking (e.g. flats) etc.

Have you have only considered hydrogen for HGVs and not for domestic vehicles?
We do have some hydrogen vans (and cars and bikes) in the scenarios but electricity dominates at present.

You say that in TD there is a 10GW higher peak demand… Is there more information around why centralised charging increases peak demand as I am concerned from a DNO perspective?
On public charging, we looked at different rates of charging and the higher the rate the slower the duration. This is difficult to make the charging smart. We did look at the possibility of using larger batteries for EV charging.

In TD there could be a lot of different hubs – supermarkets, car parks etc. Public charging is less around the peak. However, if people do charge here, it is difficult to incentivise users to defer charging.

The CCC analysis shows demand nearly doubling for Net Zero. How is your analysis benchmarked?
CCC has based its advice on existing policies where as we have moved energy efficiency on from this point.

What is the impact on summer peak demand in the future?
In the Data Workbook we have published our demand data for summer as well as winter (am and pm).

Why have the assumptions around natural gas vehicles reduced?
Stakeholder feedback suggested that you would move directly from diesel to hydrogen.

Do we think there is enough Lithium in the earth's crust?
There are other battery technologies being explored which are potentially viable alternatives to Lithium Ion (e.g. Sodium Ion).

You were talking about charging hubs and what people may do whilst they are charging but charging point providers are looking at things the other way around. They look at places where people spend an hour (e.g. gym) and put chargers there.
We do speak to charging providers (including ones building charging hubs in GB and EU). We don't put all our eggs in one basket and consider a range of solutions. For instance, we combine residential and charging hubs.

On expected uptakes, are these related to economic drivers or policy?
It would be economic as we use a total cost of ownership model. This produces different tipping points for different types and sizes of vehicle.

I notice that you model economic growth as 0.9% in the two scenarios that don't meet the 2 degrees target and as 1.8% in those that do. What lies behind that? Are these percentages external to the modelling (i.e. you set the respective percentages and then model the scenarios) or does the modelling generate the percentages (due to e.g. greater energy efficiency leading to greater productivity and growth in renewables boosting UK export potential)?
Our scenario framework used to consist of two axes, economic growth and green ambition. From FES18 onwards the axes changed to, the level of decarbonisation and level of decentralisation. We have amalgamated economic growth and level of decarbonisation on the x-axis as we believe that the level of decarbonisation is likely to be influenced by the prosperity of the UK economy, i.e. more money available to spend on decarbonisation and more willingness for society to accept the financial costs of decarbonising when people have more money.

Our economic growth forecasts are produced by a third party who specialise in this subject. They produce economic growth scenarios on a total UK basis, as well as breaking it down into forecasts for 24 individual sub-sectors of Industry and Commerce which feed into our I&C energy demand modelling. The I&C demand modelling uses regression analysis where the two explanatory variables influencing gas and electricity demand are: sub-sector output and energy prices (outright and relative to other alternative fuel options).

Our GDP forecasts also drive the uptake of EV's and residential electricity demand through the number of appliances.

I'm looking at the South Yorkshire relevant regional breakdown of FES data. There are 13 GSPs in the county, but I can only see 10 of them in the Excel breakdown (the three omitted are Brinsworth, Stocksbridge, and Aldwarke). Can you please explain to me why this is?
The regional breakdown includes those GSPs as included on Elexon's list. Note that a GSP is defined as an interface between the transmission network and the distribution network. The other type of offtake from the transmission network is the large industrial "Direct Connect" customers. Both Brinsworth and Aldwarke fit into this category. Stocksbridge is a transmission network only substation with neither a Distribution network nor a Demand Direct Connect customer attached here – it is transmission on both sides of the transformer.

Electricity Supply

Thermal

The load factors for gas fired power stations reduces in some of your scenarios. How will the business model work for these sites in the future?
We acknowledge that the low load factors for gas-fires power stations will make their economics more challenging. In fact, we mention this in the FES document, where we say that the economics of these stations will be increasingly reliant on their ability to provide flexibility to back-up renewables and network services. In addition, the ESO has an ambition to operate the system with zero carbon by 2025, and this may change the services we require, as we respond to the changing market.

If CCUS reduces the efficiency of the power station it may limit the growth in CCUS. Are your projections too high?
We explore a range within our scenarios including no CCUS in the Community Renewable scenario. We don't create an over-reliance on CCUS and note the role it plays in the Committee on Climate Change's work on Net Zero.
Our assumptions are backed up by how BEIS have already identified these clusters and hydrogen production / industry. We look to locate our CCUS generation in these sites. For example, power stations will be clustered and coupled with industry that are ready to use CCUS applications like cement production, fuel and chemical synthesis for example.

You project 12 GW of carbon capture utilisation and storage (CCUS) in Two Degrees. What is the load factor you assume?
In Two Degrees, the load factor in 2050 is 11%. For Steady Progression, it is higher at 49% as we assume the CCUS needs to run to pay back the cost of the infrastructure, while it can run more flexibly in Two Degrees, as the CCUS is also needed to produce hydrogen.
For the results of our dispatch model please see table ES1 within the data workbook. You can use this data to calculate load factors for all technologies.

Nuclear

What scope do you think there is for other technologies to step up and take up the baseload role from nuclear?
We have a range of different nuclear capacities across the scenarios. We also consider a range of other technologies many of which could provide baseload generation. For example, Biomass fuelled, CCUS and gaseous fuels. We also see a potential for various new types of nuclear reactors, some of which could be flexible or semi-flexible in terms of load response.

Renewables

Why are the solar projections lower than last year's scenarios?

Solar projections are similar for three out of the four scenarios but much lower in Community Renewables. As part of the call for evidence we received some challenge on the high case, which also included challenge on how much solar the market can accommodate. We engaged with stakeholders in the solar industry to develop the revised view balancing the need for decarbonisation and security of supply.

The offshore wind projections have increased from last year – why is this?
We have revised the offshore wind projections upwards. This is driven by several things including:

- Technology developments and falling costs – wind farms connecting in the mid-2020s could have turbines > 10 MW, which has helped reduce costs with some studies suggesting offshore wind could be cheaper than onshore wind by 2030.
- Sector Deal – sets a target of 30 GW by 2030 but also provides more clarity on the timing of CfD auctions.
- Crown Estate committed to further development with additional 7 GW to be made available in Round 4.
- Increasing push for accelerated decarbonisation. Offshore wind is a good candidate giving relative ease of scaling, planning permission, construction and improving load factors.

Onshore wind projections are lower overall than last year – why?
We had a lot of challenge on the high levels of onshore wind in Community Renewables last year based on access to suitable sites and planning permission. The cost reduction of offshore wind was also considered as a factor as noted in the answer to the question above.

Some low-cost forms of generation cannot compete in CFD auctions – how do you think they should be brought forward?
We do not assume the method by which technology is brought forward as there are many possible routes to achieve this. We do however acknowledge that to meet the level of growth seen in some of the scenarios the current restraints will need to change. This is particularly true with the 2050 timescale to meet the carbon targets. That is, we make some assumptions to help growth but it is still uncertain as to the detail of the changes required.

Are you placing too much emphasis on solar and wind? Would a future with more tidal/wave power deliver a more balanced portfolio?
We include these technologies within some scenarios and the data is available in the data workbook. There have been challenges developing these technologies and they are not as prevalent as solar or wind. This increased uncertainty is reflected in our scenarios.
We will continue to review the tidal and wave sectors as part of our ongoing stakeholder engagement. If more evidence comes to light we will reflect this in a future publication.

Is black bag waste used (as not allowed in Scotland now)?
We have developed our waste growth based on known projects within the first few years, and the limitations within the Committee on Climate Change projections in the long term. We believe that both are compliant with the restrictions.

For distribution-connected solar PV, you say that it will mostly go into the southern region and work its way north. Do you have more information on this?
We publish regional data alongside the FES Data Workbook which contains more detail in this area and is developed with the TOs. If you look at current solar installations, there is a predominance in the south as conditions are favourable. We agree that as more solar capacity is deployed there, network capacity could be limited which could prompt a move northwards. Similarly, this could happen as costs of solar reduce.

Interconnectors/Europe

Do you vary the European assumptions for different scenarios?
Yes, we vary key input assumptions like generation, storage, demand, fuel and carbon prices and non-GB interconnectors. We model Europe using scenarios developed by ENTSO-E and other European TSOs. We include a full list of our sources in the Modelling Methods document.

All scenarios rely on Interconnectors for demand but during periods of no wind in neighbouring countries these may not be exporting to GB. Is there need for a more complex analysis and stress testing?
All our scenarios meet the reliability standard of 3 hours Loss of Load Expectation (LOLE) per year. In GB, this is delivered through the capacity market. As we get closer to real-time, we carry out detailed modelling with a wide range of stress tests in both GB and Europe to determine the capacity to secure in the auction. This analysis is published annually in the Electricity Capacity Report and scrutinised by BEIS' Panel of Technical Experts.

For electricity grid carbon intensity are interconnectors considered zero carbon as they are Scope 3 emissions?
In FES 2019, we have continued to calculate emissions based on those produced domestically within a country as this is the current, accepted way of doing this. This means that interconnector imports are considered as zero carbon. However, any interconnector exports from thermal generation would be included in Great Britain's emissions.

Have you modelled what the energy mix being delivered to GB via the Interconnectors will be in each scenario?
In FES 2019, we have continued to model European countries based on scenarios developed by ENTSO-E and other European TSOs. We provide reference to these scenarios in the Modelling Methods document.

Storage

What assumptions have you made around storage in the modelling?
Our storage assumptions are based on assessing the combination of how much we need (i.e. how much renewable generation we need to shift) and the potential pipeline of projects. We consider both short and longer duration storage based on de-rating factors used in the capacity market. This includes different storage technologies such as batteries, pumped hydro, compressed air and liquid air.

Do we have hydrogen for electricity storage?
No, we currently have assumed no use of hydrogen in electricity storage. Storage in our scenarios includes battery as well as pumped storage, compressed air and liquid air. We regularly look at options for longer term storage (including heat, large scale hydrogen and others). If you have evidence in support of these please provide feedback via our consultation.

Is there a growing case to include storage and potentially electrolysis in the NOA?
NOA Pathfinder work already looks at solutions other than just network investment (e.g. storage, electrolysis and DNO solutions).

Pumped hydro grows from 30GWh capacity today to 56-105GWh in 2050 – where has this assumption come from?
The assumptions on storage are based on a combination of how much storage we need (e.g. the need to shift renewable output, based on some dispatch modelling) and the pipeline of projects that we have intelligence on (some of which may not be in the public domain – although there are some new projects listed on the TEC register).

Security of supply

When there is extended period of high demand and low wind will there be enough electricity generation?
All our scenarios meet the reliability standard of 3 hours LOLE per year. In GB, this is delivered through the capacity market. As we get closer to real-time, we carry out detailed modelling with a wide range of stress tests in both GB and Europe to determine the capacity to secure in the auction. This analysis includes the consideration of a variety of historic weather years to look at variation for peaks and outliers. It is published annually in the Electricity Capacity Report and scrutinised by BEIS' Panel of Technical Experts.

How does National Grid ESO engage with government to ensure security of supply will be met? Are outputs of the Future Energy Scenarios shared widely enough to ensure the growth in generation capacity will happen?
National Grid ESO undertakes analysis each year to recommend the level of capacity to secure in the upcoming auctions to ensure we meet the reliability standard. This analysis is provided to BEIS and published in the Electricity Capacity Report. The work is scrutinised by their Panel of Technical Experts. We endeavour to share the outputs from the FES as widely as possible and have a well-developed stakeholder engagement process to publish the work and allow stakeholders to provide feedback.

Oversupply

You have indicated period of oversupply beyond 2020 - does this account for storage and exports?
In the faster decarbonising scenarios of Two Degrees and Community Renewables, there are periods of oversupply of electricity beyond 2030. The annual amount of excess electricity rises to 20–25 TWh (around 6% of total annual output) after 2040 in Community Renewables. Our modelling shows that at times of likely oversupply, excess electricity cannot be exported, as other countries that have decarbonised are likely to be facing similar issues. Nor can it be stored, as available storage is full. That is, the numbers we present are the result after storage, demand response and smart engagement has been accounted for.

Have you reduced modelled system oversupply scenarios through possible load shifting/smart EV charging patterns etc.?
Yes. As part of our analysis we run a dispatch and include multiple forms of demand; some of these are semi-flexible, or fully flexible. These demands can shift to when the price was low to fulfil those demands.

Does this oversupply include system constraints or is it focused on energy?
The annual excess electricity is solely focused on energy; one of the underlying assumptions in FES is an unconstrained network. We continue to explore the implication of the FES scenarios on system and network within the Electricity Ten Year Statement and Network Options Assessment publications.

What is the impact of oversupply? And what can be done about it?
Our modelling shows that there could be short-term 'spikes' of excess electricity, and some more prolonged periods of oversupply. The oversupply issue isn't unique to us - this is also evident from work done by other TSOs within ENTSO-E; and appears in numerous industry consultant's analysis of future systems.

Ultimately, future markets will determine how this electricity could be used, stored or curtailed in the most efficient way. You can read more on page 125 of the FES document. In FES, we highlight the issue, and the need for a market response to this pattern of oversupply; rather than stifle innovation from the market by suggesting a solution.

As new markets develop we will reflect these in our analysis. This will further reduce the level of oversupply beyond the reductions we have built in by accounting for storage, demand response and smart technologies.

How much oversupply would there be in a net zero scenario?
So far, our net zero analysis is a sensitivity rather than a full scenario. What this means is that we have not undertaken the full detailed analysis that we use to develop scenarios. We are therefore unable to provide an answer at this stage. We are currently considering the scenario framework for FES 2020. If we model net zero as a full scenario we will produce the data then.

Other

Do you look at cost of the supply mix? What could Balancing Costs look like in 2040/50?
We have now costed the FES 2018 scenarios, and the results of this work were published earlier this year via webinar, which can be access from the FES website. As we have not made fundamental changes to the scenario framework this year, we have not repeated this costing work for FES 2019. As we move to Net Zero scenario(s) this could be an opportunity for us to re-visit costings.

There are some step changes between 2018 and 2019 in the decentralised generation data within the ES1 worksheet. What is the reason for these?
The difference you see here is due to the way distributed generation is modelled. We start by reviewing historic load factors – these are then used in our calculations of underlying demand (i.e. transmission demand plus the assumed amount of distributed demand). From an initial starting point in 2018 we project the demands forward as described within the energy demand chapter. The data from 2019 onwards in ES1 is the result of our power dispatch model. This is a pure economic model which assumes an unconstrained network. Whilst we work to keep the model results reflective of the outturn, it is a simplification of a complex market (with an unconstrained network being one of the bigger simplifications) and hence the changes observed.

Why is there a large drop in carbon intensity from generation between 2018 and 2019?
The carbon intensity of generation for future years is all calculated from the economic dispatch we run with in the BID3 power dispatch model; as the dispatch is purely economic it does not account for any network constraints which may cause a higher carbon intensity. The 2018 carbon intensity comes from carbonintensity.org.uk as an average of the whole year.

Do you rule out any generation projects based on existing network constraints?
No. We're not ruling projects out based on the current constraints of the network. No assumptions are made in relation to network restrictions. The results of the Future Energy Scenarios are used within the ETYS and NOA analysis to identify network restraints and potential solutions to these.

It would be useful to know sensitivity to fuel price to some of your scenarios/assumptions. Is this a place you can be more transparent about in future FES documents?
Each sub-component will have different sensitivity to changes in prices or subsidy mechanisms. We saw a marked change in the rate of deployment of renewable generation following changes to subsidies in 2018. There are however multiple routes to market including options that explore different revenue streams for each generation technology. Distilling this into a one size fits all summary would be an over-simplification of the market.

Can you publish generation volumes for all scenarios please?
Please see the ES1 tab in the data workbook.

Within the data workbook there are commodity prices for Gas, Coal, Oil and Carbon. Is there a commodity price forecast for electricity as well?
We are not assuming an average annual approximate electricity wholesale price for FES this year like some previous years. We presume wholesale price varies hourly or for optimisation periods in

our modelling. Fuel/Carbon prices as well as generation/demand and net imports costs will be used as inputs to determine wholesale prices for a particular hour/period during FES BID3 modelling.

CO2 intensity in 2030s drastically reduced in 2050 compliant scenarios (TD/CR reach ~15-18g/kWh in 2035) – why was this decision taken? How is it achieved?
The CO2 intensity for the power sector reflects the generation mix needed to meet the carbon targets (it's an output rather than an output). It will have come down between these years given that we have more renewable output (particularly offshore wind) greater flexibility provided by low carbon technologies. Lower annual demand in Community Renewables will also result in lower emissions from generation.

Gas Supply

Why don't we have hydrogen as an "international commodity"?
Have we considered hydrogen imports?
We have not yet modelled any imports or export of hydrogen. This is something we may look at in more detail for FES 2020

What is happening between 2030 and 2050 to get to the total of green gas?
There is a pull from heat but we note there is also a degree of uncertainty around different projects. We assume green gas advances at the top end of our scenario range.

How do shale figures compare to FES 2018?
They seem high. Also on steady progression, as we have seen shale gas has been at a standstill for the last 7 years, yet its relatively high. In previous year's we have had two high shale cases. This year we have a high case in Consumer Evolution and a Medium case in steady Progression that is roughly half of the High case. We have taken data from UKOOG – looking at both fracking and drilling for shale gas.

Do you think 12 bcm of biomethane in realistic?
What needs to happen to see 12bcm is policy from government, alongside technological advancement – which is not currently commercially viable.

Biothemane production so far is rising year on year, the grow of biomethane industry depends on government policies, additional subsidies can accelerate the speed of development. Given UK's ambition to achieve zero emission world by 2050 might suggest more support for green gas industry.

Do you look at gas from anaerobic digestion?
We do look at anaerobic digestion that is connected into the distribution system.

Do you see a role for electrolysis in hydrogen?
Electrolysis is in the mix for production of hydrogen in our scenarios.

Netherlands have a lot of electrolysis in their scenarios. There are a lot of imports in the scenarios are these combined with CCS. Where there is SMR this would be combined with CCS. There is also Electrolysis for creation of hydrogen in Two Degrees.

Hydrogen was in a scenario for another session. In Gas supply is this pure natural gas.
Gas supply section of FES 19 is purely natural gas, however some of this gas is being used to create hydrogen via SMR

All the scenarios contain a reasonable amount of gas using CCS. Has there been any consideration of no CCS?

We are looking at the range of scenarios. In community renewables, we see a low level of demand because of electrification. For net zero – we feel CCUS is vital to deliver this. This will be a factor that we will want to explore more.

Supply stats – on non-compliant scenarios is it shale gas pushing out Norwegian gas?
Shale gas in consumer evolution is pushing out Norwegian gas due to cost and having it centrally located.

Gas supply, do you consider gas security and price to consumer?
The security of supply measure that we consider as part of the FES analysis is the N-1 check, where we look at what happens if we lose our biggest asset in the UK. In all scenarios, we say peak will be met. In N-1, 3 of 4 scenarios all the way out to 2050. In steady progression N-1 is breached in the 2040's, if we were to follow steady progression there is additional work to address this, however as it is so far out we are not concerned. As we have enough gas to meet demand.

Import dependencies are much more crucial in gas than in electricity. Can you give information on the price triggers, specifically for LNG?
UKCS is the cheapest gas we can get now, then Norwegian as its most flexible, by 2050 we look at it being very different. In our analysis, we don't use any detailed prices, we look at if we are going to be reliant on gas and then match this with supply.

Gas storage, do we assume they all stay open?
We assume storage remains available at the same capability that we have today.

Linked with that N-1 do you look at coldest week/coldest point. Are you only looking at infrastructure for N-1 looking at coldest day not coldest period?
The test looks at the 1/20 where we only look at coldest day. Further numbers are available in the data workbook.

What do you classify as "green gas" is hydrogen or hydrogen blending included as green gas?
In our analysis, Green Gas is gas produced from Bio resource.

Do you see a role for power to gas for gas supply and / or system balancing?
Power to Gas has not been included in FES 19. Further research will be completed this year.

I'm surprised by the very low forecast of green gas usage. Is there a particular reason why?
Total output of green gas for all scenarios follow different underlying assumptions within each scenario. Two degrees has a highest level of green gas flown inside transmission system and local networks. We do not project green gas consumption outside transmission and local networks system. Our results are always benchmarked by other studies related to the topic. The amount of green gas can be produced in UK is a function of bio resources availability.

Is there sufficient import capacity to deliver the LNG tranches in the scenarios PLUS assume all the generic imports tranches are provided by LNG?
Yes, we test the generic import category against it being 100% LNG or Interconnector and ensure that it does not breach the capability of either.

Understand shale uncertainty, but only including it in scenarios that do not meet 2050 80% targets sounds as though those are linked. Shale has not been included in the two scenarios that meet the target as in the framework, these scenarios would require a level of consumer backing and at the moment shale does not have public support.

Whole System

Are electricity prices resulting from your scenarios available anywhere (e.g. even on a yearly level)?

No, we don't provide this information. Our electricity modelling does provide marginal generation price (this is not electricity price), but to avoid confusion and potential market distortion, we do not provide this as part of our FES outputs.

Net Zero

Why is your electricity demand around 100TWh less than the CCC? This is a 6th of the 2050 demand.
There are multiple factors adding to why our electrical demand is lower than CCC in the net zero sensitivity. Firstly, the assumption on efficiency of domestic appliances and thermal efficiency are both higher in our modelling than in the CCC report.

Another contributing factor offsetting the electrical demand is that we have gone for a lower level of electrification of heat in favour of hydrogen. A Large portion of our hydrogen is produced from steam methane reforming (SMR) and a smaller portion is from electrolysis. The Hydrogen from electrolysis would be used in the transport sector.

How confident are you with your BECCS assumptions?
We have constrained the amount of bio resources to the level from a CCC publication. A over 50% of this bio resource is used for BECCS in our NZ scenario.

From your slide - peaking plant has CCUS on them. Would it make more sense for it to be hydrogen? What happens to the networks?
We have looked at this. The way our model works starts with making sure we meet the demand and then works back on a merit order. Potentially this model isn't optimised for a world where we are net zero and not much hydrogen.This is an area we will explore when we move from the next zero sensitivity into a scenario modelling.

Gas demand in 2050 is 410 but in the CCC it is 600. Feels close to TD- Thought it would be higher than 600? Is the plan next year to do a net zero scenario?
The main difference lies in the fact that CCC net zero has higher level of natural gas in power generation, whereas in our net zero sensitivity, natural gas demand in power sector is very limited. Also, CCC net zero has some gas boilers in buildings to provide heating while our net zero sensitivity there is no gas boiler left in buildings.

Within Net zero does it include shipping and aviation? Does your response mean you assume they've solved their own problem?
Emissions from shipping and aviation are included in "Other" category. We have not optimised this as it is not our area of expertise hence, we used the numbers that CCC Net zero used.

Power generation from various sources – slide 7 – wondering in 2050 in net zero scenario whether peak demand can be covered with dispatch- able supplies?
Yes, we can meet peak. We used the same conditions as we did for the other 4 scenarios.

What are the numbers of on shore vs offshore wind?
The total wind generation capacity is 91GW with offshore capacity at 67GW and on shore capacity at 24GW.

What is the breakdown of biomass? Is there anaerobic digestion – what role does house hold waste play?

The biomass covered in our analysis are mainly wood pellets and agriculture residuals. We haven't looked at household waste in detail in our analysis.

With biomass, a lot of the time we can end up transporting it from one place to another. It is rather heavy. Have we put in any assumptions for any increase in energy/resources to create negative carbon credits?
If transporting by road we have decarbonised all road and rail by 2050 in this sensitivity. We haven't included the shipping/international transport of this. We haven't modelled the exact location where all the bio energy comes from therefore do not have an exact figure for the emissions created in transporting the fuel.

V2G assumptions – exceeding 1GW by 2030-35 seems high. Can you explain this?
In net zero have only looked at the 2050. In 2050 we have the same level of V2G as TD, as V2G works as a form of storage to provide flexibility at peak, with high electrification level it helps to make sure the peak demand is met.

Did you calculate if there are sufficient storage for carbon? I.e. from gas supplies.
The numbers below are the breakdown of carbon stored in CCUS. This number is for the year 2050 and is not accumulative.

MtCO2e	**Our net zero**
Power Sector - Natural Gas CCS	3
Power Sector – BECCS	37
Industrial Sector	21
Hydrogen Production	64
Total CO2 captured	124

We reflect the use of CCUS in the scenarios (none in CR). Assumptions are backed up by how BEIS have already identified these clusters and hydrogen production / industry. We would look to locate our CCUS generation in these sites. We don't create an over-reliance on CCUS but note the role it plays in the CCC work on Net Zero.

You don't seem to have considered the "decarbonisation of gas". Now that coal has gone, gas will be next. If there is less gas, have you considered what might happen if there is no gas (like there is no coal now)?
In all our scenarios, we have a reduction in gas demand. In CR where we have the highest level of consumer engagement and in this scenario, we see gas demand reducing the most. We consider the public view of natural gas.

Is there anyone from Ofgem interested in FES? There is a consistent triangle of BEIS, Ofgem and NG saying that there is no need for long duration storage.
We engage heavily with Ofgem on FES. As part of the ESO licence Ofgem must be comfortable with the scenarios and the level of stakeholder engagement involved in deciding them.

Could a Net Zero scenario not be delivered earlier and could the other scenarios be pushed further forward (as there is a degree of urgency now that might mean that the normal FES cycle is less appropriate than usual)?
There will be further development of the Net Zero work in the "So what of FES". This will be produced in the interim between now and FES 2020.

In your recent report, I've seen that you have produced a sensitivity analysis of your 4 scenarios to show what a potential 'net zero' scenario might look like. I have seen the number '0.35 MtCO2e' in Table 6.1 (Page 157 of the 2019 report) but have not seen a likely trajectory from current year to 2050 in line with the net zero target. Is this something that you can provide? It would also be useful to see the trajectory presented by carbon intensity of the grid (tCO2e/kWh).
Our analysis focused on 2050 and therefore there is no trajectories now for net zero.

Will Net Zero be a full scenario in FES 2020?
We will be engaging with the industry to understand the requirements or next year's scenarios.
What's the level of carbon intensity in NZ?
The Electricity grid carbon intensity is (- 67.4gCO2/KWh)

What's the levels of intermittent generation curtailment in NZ?
We have not studied Net Zero to this level of detail yet. Depending on the scenarios next year this will be covered.

What's the difference in system costs between TD and NZ?
This is not a level of detail the Net Zero Analysis has gone into yet.

What are your assumed capture rates for gas ccs?
Our assumed capture rate is 90% for gas CCS plant.

You say heating is net zero, where are the emissions from the production of the hydrogen for heating accounted for?
The emissions to produce hydrogen is counted in the SMR production phase.
As the new compliant scenario is net zero, rendering TD and CR 'non-compliant', will SP and CE be dropped from future FES documents as 'super non-complaint'?
We will be engaging with the industry to understand the requirements or next year's scenarios.

Can you envisage a net zero scenario if low carbon hydrogen is not feasible? Community renewables plus?
Our scenario is by no means the only way to reach Net Zero. We have focused our analysis on a world with Hydrogen. Depending on the outcome form the industry engagement we may consider this in more detail in next year's scenarios.

You say NetZero is achievable but none of the scenarios give any idea of costs involved to industry and customers to get there. Are the costs feasible?
As a sensitivity, we don't provide costs. Net zero is achievable because with the tried and tested technologies available today and the known potentials of other technologies ours studies show it is possible to reduce the greenhouse emissions to net zero by 2050. By this point we would expect many green assets to have fallen in costs with economics of scale and technology improvements.

Whole System breakout: why under the NZ scenario does Biomass + CCUS displace Solar (vs the CR scenario)?
Our net zero sensitivity is based on TD, which favours centralised generation. It shows how the electricity generation capacities must stretch further to reach net zero.

The generation capacity in the net zero sensitivity is modelled through BID3, and the resulting generation mix provides a balanced solution that there is sufficient electricity supply to meet demand, the winter peak is met, and there is enough thermal generation such as Biomass + CCUS to provide stability to the system.

Biomass and CCUS has also been key in our studies to producing negative emissions and countering other, harder to decarbonise, sectors.