TBE 2011: Development of Energy Scenarios

14 July 2011

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TBE 2011 – Development of Energy Scenarios

Foreward

As part of our annual Transporting Britain's Energy (TBE) consultation process, the principal purpose of this document is to set out our assessment of the future demand and supply position for natural gas in the UK.

We have continued the approach of developing and updating two detailed demand scenarios, Slow Progression and Gone Green. Gone Green is a "top down" scenario that depicts our views of the plausible energy mix under the assumption that the 2020 environmental targets are met. Slow Progression is more of a "bottom up" scenario that shows the energy mix based on existing or soon to be implemented energy policies that move the scenario towards achieving the targets but at a later date of around 2026.

Each year, we ask for feedback on the outputs from the Transporting Britain's Energy consultation process. Last year, we received a number of responses requesting that we make the Development of Energy Scenarios document more effective by highlighting and summarising key messages, as well as releasing the underlying data to enable interested parties to undertake their own analyses. Consequently we have revised the format and content of this year's document.

The three key messages from this year's Development of Energy Scenarios document are:

Climate change: the challenge of overhauling the generation mix in the UK from 2011 to 2020.

Affordability: the policy debate necessary to decide the appropriate balance between gas and electricity generation.

Security of Supply: Ensuring both the electricity and gas networks are capable of meeting the challenges of an energy future that includes a significant level of renewable generation with more variable output and demand.

We would welcome feedback on the issues raised by this paper. This feedback, together with signals received from entry capacity auctions, will assist us in identifying appropriate energy scenarios and long-term developments to the NTS and presenting plans that reflect these developments within our next Ten Year Statement, which we will publish towards the end of 2011. It would be helpful to receive comments by September 1st 2011.

Feedback should be directed by e-mail to:

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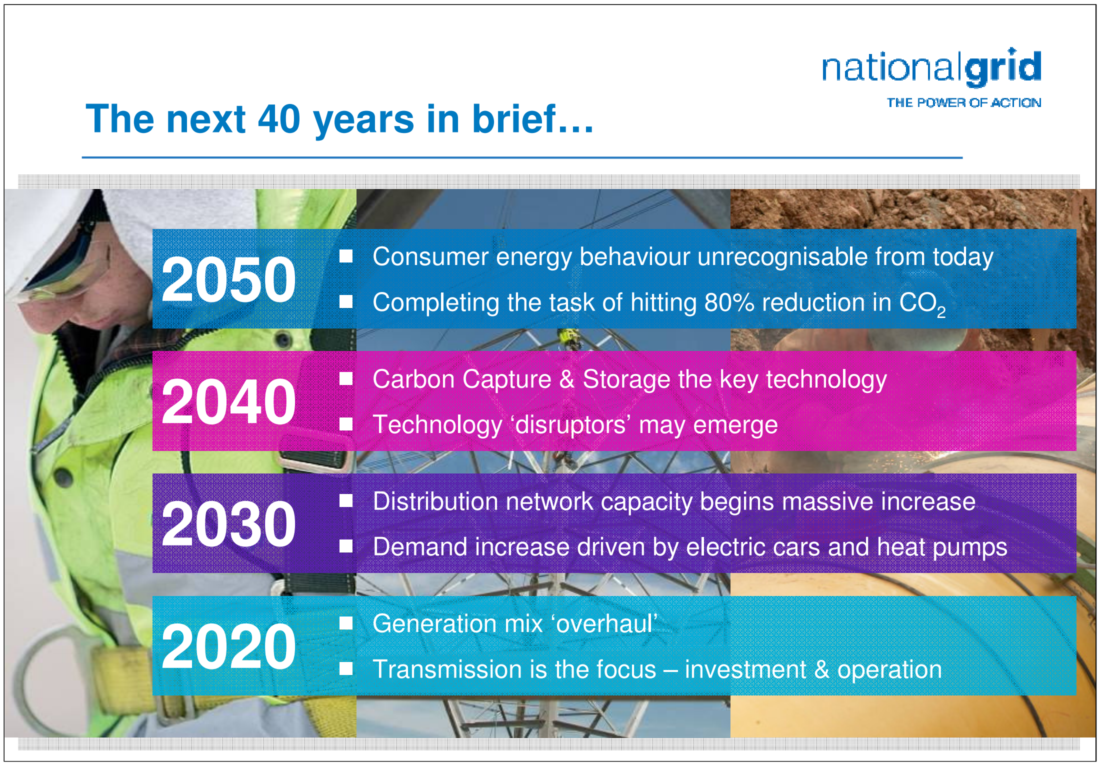
Future of energy

Richard Smith
Future Transmission Networks Manager

Transporting Britain's Energy – 14th July 2011



The energy industry between now and 2050 is set to change dramatically, driven by the need to provide secure, affordable and low carbon energy.

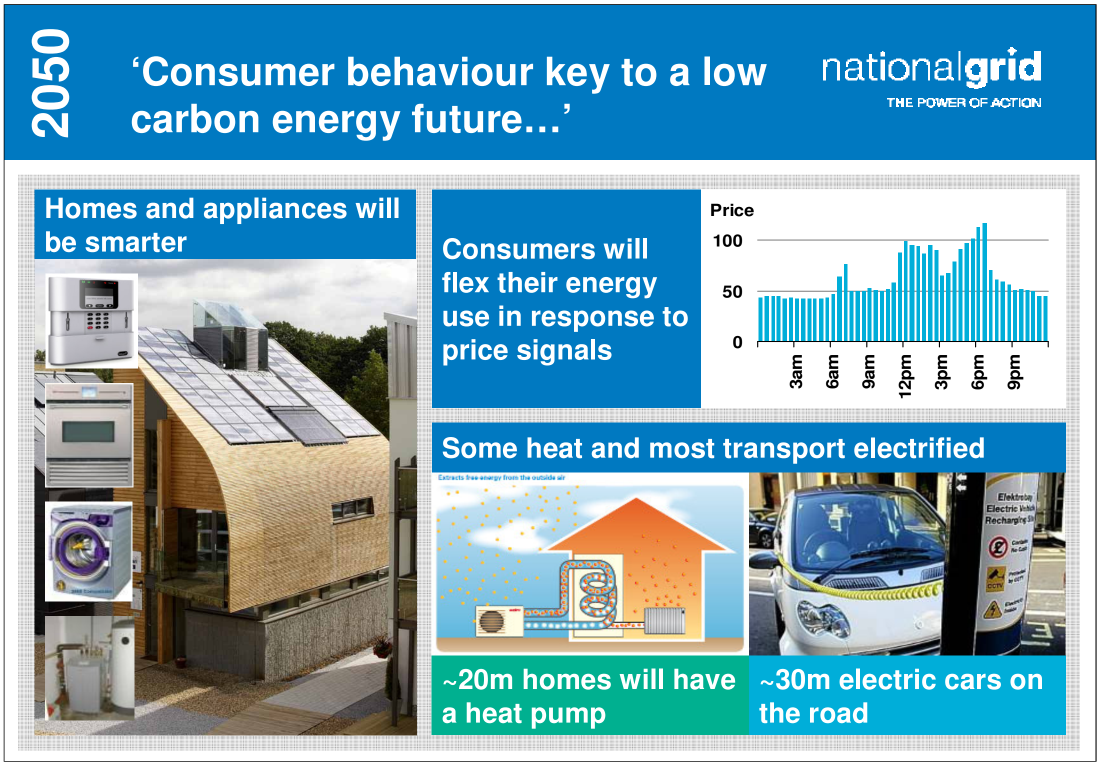
The path to low carbon energy is driven by UK Government targets for emissions and renewable energy, which ultimately deliver an 80% cut in greenhouse gas emissions, compared with 1990 levels, by 2050.

At National Grid, we have examined how the challenges of meeting 2050 climate change targets might be met. We recognise that there are other scenarios that have been produced that look at how 2050 targets are likely to be achieved but believe that our role at the heart of the energy value chain puts us in a unique position to comment.

To achieve the Government targets we need to understand the evolution of the 2050 vision and how we can achieve the end goal of decarbonisation, and what the major themes will be within each decade between now and 2050. The themes we identify should not be interpreted as the only issues or events in any given decade, rather they represent the biggest changes, behind which there will also be a large number of other issues or events that, although of a lesser magnitude, are still important.

2040 – 2050

Consumer & Completion



The decade ending in 2050 is dominated by two key themes, the engagement of consumers and their willingness to change the way they use their energy; and completing the decarbonisation of the energy mix.

They will need to be responding and reacting in their energy consumption habits to signals around carbon and time of use pricing. Homes and appliances will be far more sophisticated, with smarter white goods, heating appliances and vehicles as low carbon solutions to demand loads evolve. For example, based on current behaviour, between 2011 and 2050, the average household will have changed their boiler four times, their white goods seven times and their car ten times.

While the evolution of these products will be driven by consumer behaviour, manufacturers have a major role in bringing solutions to market, which, through ease of use encourage full adoption by consumers and active, possibly automated, engagement with energy markets and systems.

We expect that by end of this decade most cars will be fully electrified and around 50% of homes will be fitted with heat pumps.

Although consumer behaviour will be a key factor in achieving the climate targets, requiring a much higher level of engagement than today, it is important to recognise that there will is a long lead time to encourage consumer habits to change, and both education and incentives can play a part.

2050 Where will our energy come from?

~50% from electricity at ~15g CO_2(e) / kWh

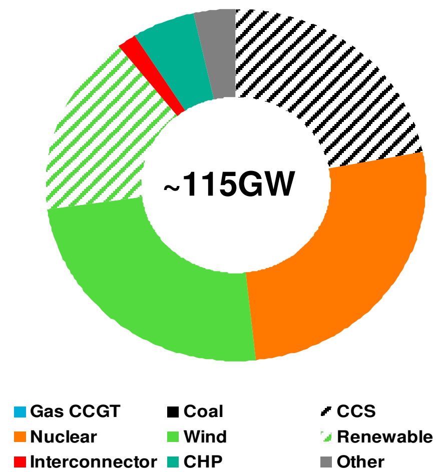
- Wind, nuclear & CCS dominant at ~25GW – 30GW each
- ~20GW other renewables
- ~15GW interconnection
- ~20GW embedded generation

~35% from gas at ~185g CO_2(e) / kWh

- LNG & continental imports
- Bio-methane

~15% from oil at ~245g CO_2(e) / kWh

Generation capacity mix



In the decade to 2050, we will be completing our journey towards achieving the climate targets and the reduction in greenhouse gas emissions. This decade will be about optimising and fine tuning how we meet the targets, optimising the way that demand and supply are utilised to balance the system, and utilising decarbonised electricity as the principal energy resource.

Around 50% of end use energy will be in the form of electricity up from 15% today. With carbon capture and storage, nuclear, and wind each comprising 25 – 30GW of the power generation mix, the carbon intensity of electricity will have fallen dramatically from around 500g CO2 (e) / kWh today, to around 15g CO2 (e) / kWh in 2050. The significant electrification of heat and transport is therefore highly logical by this decade, and electricity demands will have risen by over 50% to around 555TWh annually.

Some 35% of our end use energy will come from gas. At a carbon intensity of around 185g CO2 (e) / kWh when burned in the home, this will largely be used for some industrial processes and space heating, providing an affordable and secure solution to meeting heating demands, particularly in older properties and at the coldest times of the year. This gas will be supplied to the UK market through LNG and continental imports, as well as from bio-methane and other ‘unconventional’ sources.

2030 – 2040

Carbon Capture & Technology

2040 ‘To capture or not to capture? …that is the question’

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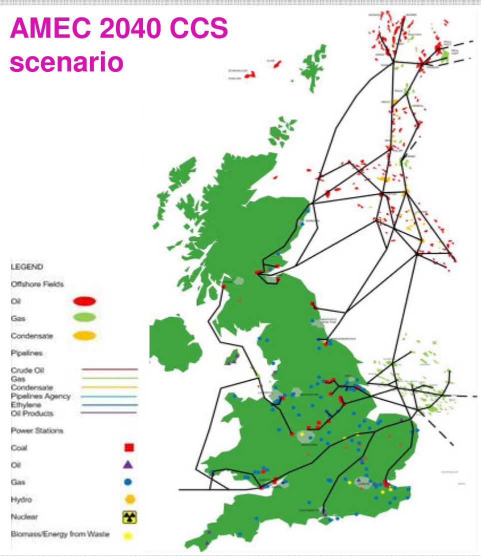
AMEC 2040 CCS scenario



Carbon Capture & Storage the key technology

- Trials in the late 2010s / early 2020’s
- Projects in planning and development in the 2020s
- Large scale deployment in the 2030s

Other developments

- ‘Replanting’ of wind generation
- ~10m additional electric vehicles
- ~6m additional heat pumps
- Bio-methane injection common-place
- Norwegian gas supplies near zero

‘Disruptive’ technology emerges?

The decade from 2030 to 2040 is perhaps the area where there is most uncertainty in considering the future of energy.

In principle, we expect the decade will be dominated by the proliferation of Carbon Capture and Storage (CCS) in power generation. We anticipate that with DECC funding, trial projects will demonstrate the technical viability of gas and coal CCS by the early 2020’s. Assuming that these trials also indicate the economic viability of CCS, we expect lead times for project development, planning, consenting and financing to result in deployment during the later half of the 2020’s and become established during the 2030’s. The prevalence of either gas or coal CCS will of course be dependent on the economics of those underlying fuel sources, and the market view of forward prices.

Simultaneously this decade has the potential to see ‘technology disruptors’ emerge that change the way that the macro emissions targets could be met. A wide variety of new innovative technologies are currently being proposed as potential solutions to low carbon energy, these are the ‘known unknowns’ and over the next 20 to 30 years it is possible that some of these could be come economically and technically viable for scale deployment. In addition, it is possible that other innovations as yet unconceived, the ‘unknown unknowns’ may emerge on the research and development radar and further alter our view of how the 2050 decarbonisation targets may be met.

2020 – 2030

Distribution & Demand

2030 every DN has it’s day…’

Peak electricity demand in the home increases significantly

- ~2.5kW peak appliance demand for an average house in 2010
- ~3kW charge for an electric car
- ~3.5kW demand for a heat pump

- ~9kW potential total demand

Distribution networks will need to double their capacity

	2010	2030	2050
Household demand*	~2.5kW	**~4.7kW**	~7kW
Embedded generation	~8GW	**~15GW**	~20GW
Network loading (kW/km)	~75	**~170**	~300
Network scale		**X2.3**	**X4.0**

** After diversity average peak demand*

Network scale vs 2010 levels

The decade from 2020 to 2030 is dominated by considerations of demand and distribution. By the start of this decade, electricity will have been significantly decarbonised, down to 200g CO2 (e) / kWh from around 500g CO2 (e) / kWh today. Therefore it is logical to significantly ramp up the deployment of electric cars and heat pumps as the carbon intensity of electricity (from the marginal plant) now compares favourably to that of gas in space heating, and oil in transport. At the same time, we will also see continuing deployment of small scale embedded generation, including for example, micro combined heat and power boilers in the home, solar photovoltaic’s, and small scale wind.

This will drive a significant change in demand patterns on electricity distribution networks. Today, the average after diversity peak household demand seen by the electricity distribution networks is around 2.5kW. Adding plug-in electric vehicles at around 3kW, heat pumps at around 3.5kW, and assuming all embedded generation is ‘helpful’ in terms of it’s location and time of production, this leads to an average after diversity peak demand of 4.7kW per household in 2030, which represents a more than doubling of the loading on today’s electricity distribution network. By 2050, with further electric vehicle, heat pump and micro generation deployment, the same analysis suggests a quadrupling of the distribution network loading.

While ‘smart grid’ technologies will enable more dynamic demand, mitigating some network constraints over peak periods, electricity distribution networks will have to invest significantly in new network capacity from 2020 to 2030.

Now – 2020

Generation & Transmission

2020 'Generation, generation, generation…'

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~20% energy from electricity at ~200g CO_2(e) / kWh

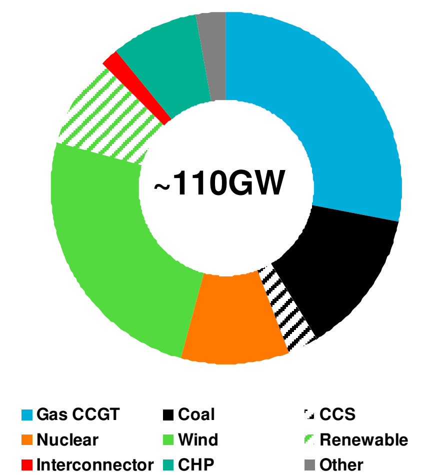
- Wind, gas dominant at ~30GW each
- ~11GW nuclear
- Some unabated coal
- ~10GW interconnection
- ~14GW embedded generation

~40% from gas at ~185g CO_2(e) / kWh

- LNG & continental imports increase
- UKCS & Norwegian gas decline

~40% from oil at ~245g CO_2(e) / kWh

Generation capacity mix



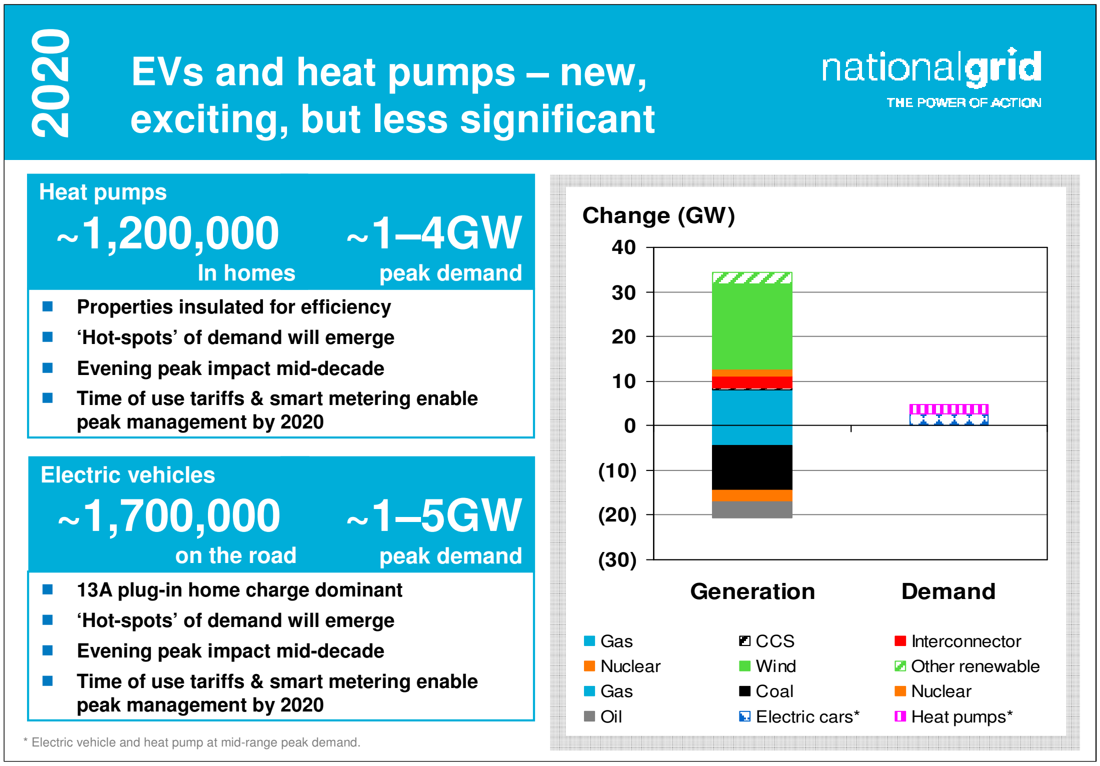
From now to 2020 the dominant themes for the industry are the changes in the power generation mix, and the transmission networks required to facilitate that change.

By 2025 around one third of the UK's existing power generation fleet will have closed due to either their age and condition, or under the Large Combustion Plant Directive and Industrial Emissions Directive.

The need for security of electricity supply will drive the construction of a new fleet of power stations, however, the opportunity exists to do this in a more sustainable way. The UK Government 2020 renewable energy target will drive the deployment of around 30GW of new renewable power generation, which is largely expected to be onshore and offshore wind.

By the end of this decade, electricity will have been significantly decarbonised, down to 200g CO2 (e) / kWh from around 500g CO2 (e) / kWh today, reflecting a roughly six-fold increase in renewable power generation, while gas fired power generation will form just under one third of the generation mix.

Note that the carbon intensities shown for gas and oil relate to the carbon content of the fuel before conversion; and in the case of gas this would be double this level for the generation of electricity assuming a 50% plant efficiency.

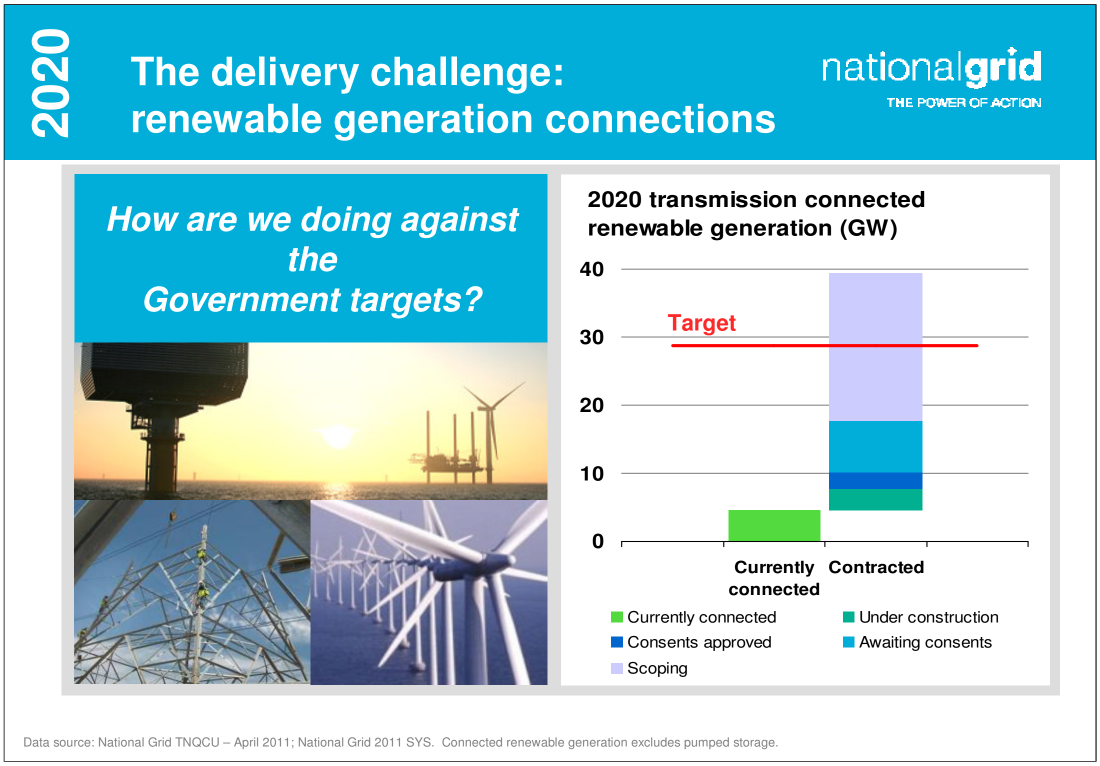


Much of the discussion around low carbon energy futures centres around the deployment of new technologies, and heat pumps and electric vehicles are among those most frequently mentioned.

Under our Gone Green (2011) scenario, we expect to see the deployment of around 1.2m heat pumps and around 1.7m electric cars by the end of this decade. We estimate that these have the potential to add between 2GW and 9GW to peak demands, dependent on the amount of flexibility that can be encouraged through smart metering and time of use tariff arrangements.

In an electricity system operation context, this is not insignificant, however, these issues are dwarfed by the more than 50GW 'churn' in the power generation fleet, and the increase wind power generation (which will be variable in output) from around 5GW today to just under 30GW in 2020.

To deliver this overhaul of the generation fleet and meet the renewable energy targets, a clear focus on investment in new power stations is critical, as is a focus on delivering the transmission network investment that will facilitate their connection.

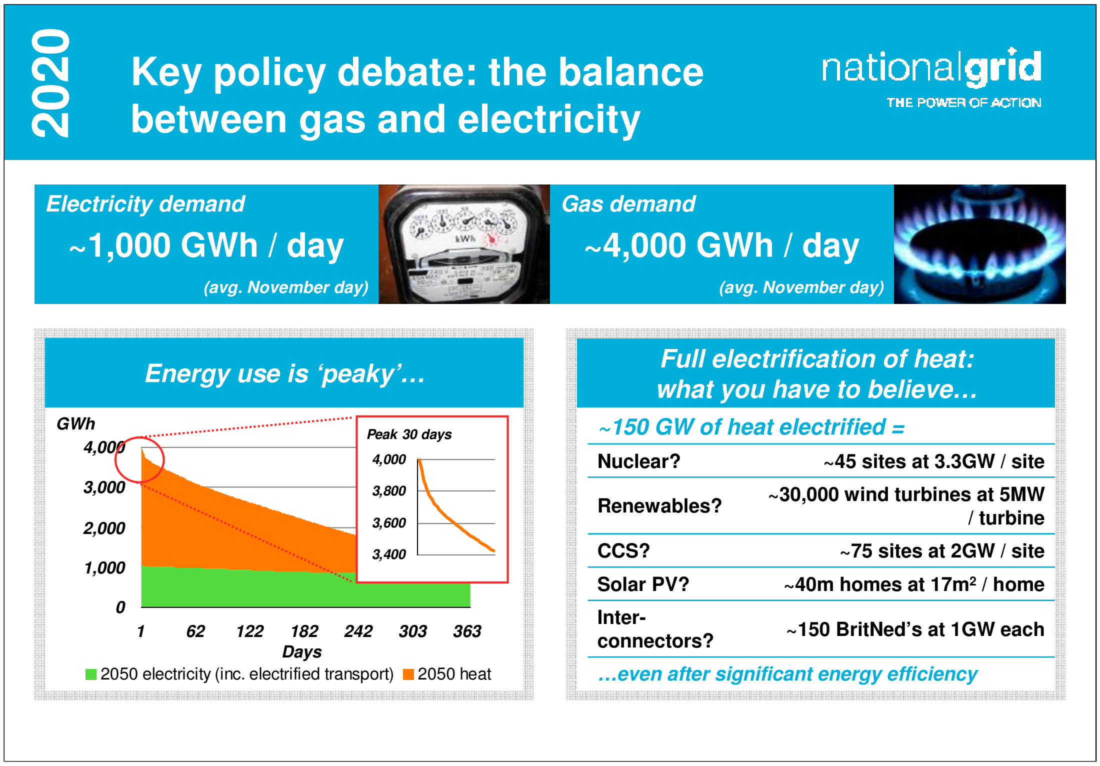


So how are we doing against the renewable energy target?

Today, just under 5GW of renewable generation (excluding pumped storage) is connected to the UK's transmission network.

We currently have just under 35GW of signed agreements with renewable generation developers for connection to the UK transmission system. 3GW of these are under construction, a further 2.5GW have approved consents, 7.5GW are awaiting consenting, and just under 22GW of projects are being scoped.

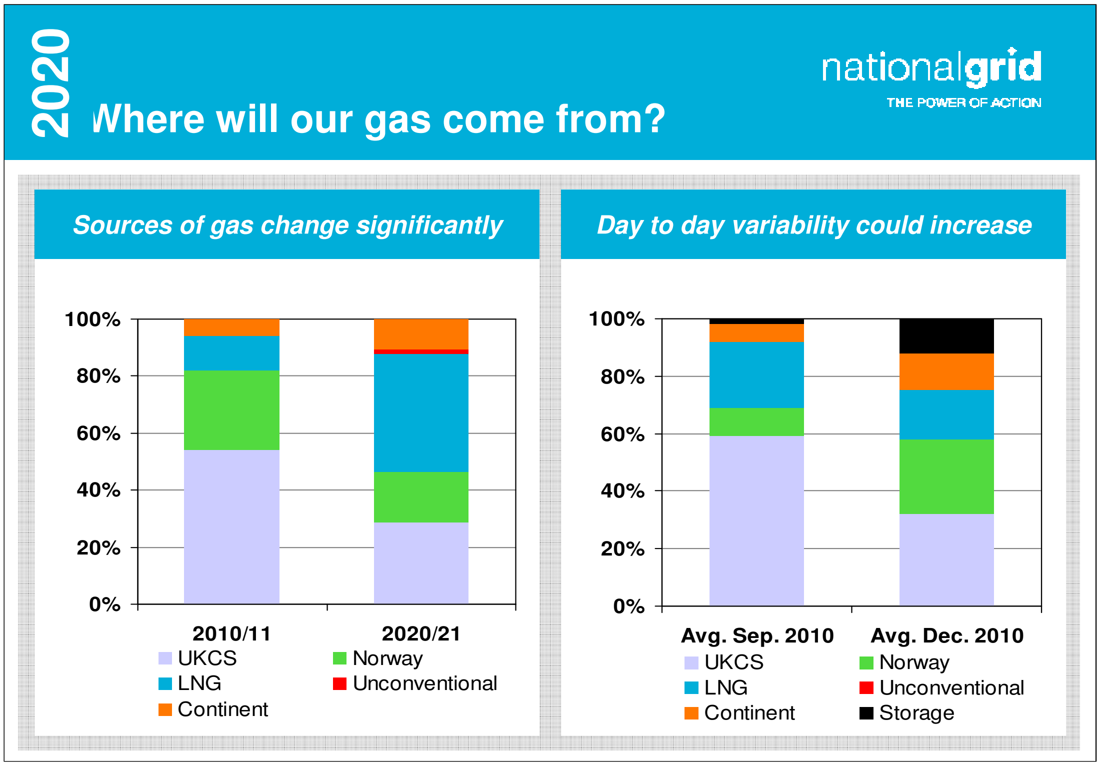
So, in total there are just under 40GW of renewable generation projects have been identified that may be connected to the transmission system by 2020. While this is more than enough to meet the power generation contribution to the Government targets, it comes with a heavy caveat – many of these projects still require financing and consenting, not all will secure that, so although on paper the UK is well positioned to meet it's targets, much still needs to be done in order to secure delivery.



The key policy debate during this decade is centred on the balance between gas and electricity. Put another way, this is a consideration of the balance between the decarbonisation of heat and affordability.

Currently, on a typical November day, four times as much energy is transported through the gas network as is transported through the electricity network. Energy use is peaky, and in particular on the coldest days of the year significantly more energy is required than in the warmer summer months.

To fully electrify this space heating requirement we would need to invest in electricity generation and electricity networks far in excess of the levels we currently see. Clearly, this is not an efficient solution. If we consider energy systems as a whole and seek to use them in a smarter way we can also ensure we deliver on affordability. This can be achieved by using gas in space heating, particularly in older properties that are less well insulated, and on the coldest day's of the year – truly 'smart' energy solutions will flex the sources of energy as well as aiming to manage and reduce the peaks in demand.



While gas will be significant in terms of the power generation mix and space heating throughout the decade, gas supplies from indigenous sources will decline to near 25% of total supplies by 2020.

In 2020, the balance of UK gas supplies will be largely delivered through LNG importation and from Norwegian and continental supplies, although unconventional sources, including bio-methane will be emergent.

With these changing sources, day to day variability in supply will increase, significantly changing flow patterns on the gas transmission network. At the same time, the variability of wind power generation will lead to increased within day and day to day variability in demands from gas fired power generation.

We have already seen this variability occur on the gas network, with the average December 2010 day appearing not dissimilar in it’s supply patterns to 2020, however, the frequency of this variability is set to increase significantly during the course of the decade.

2020 The transmission delivery challenge

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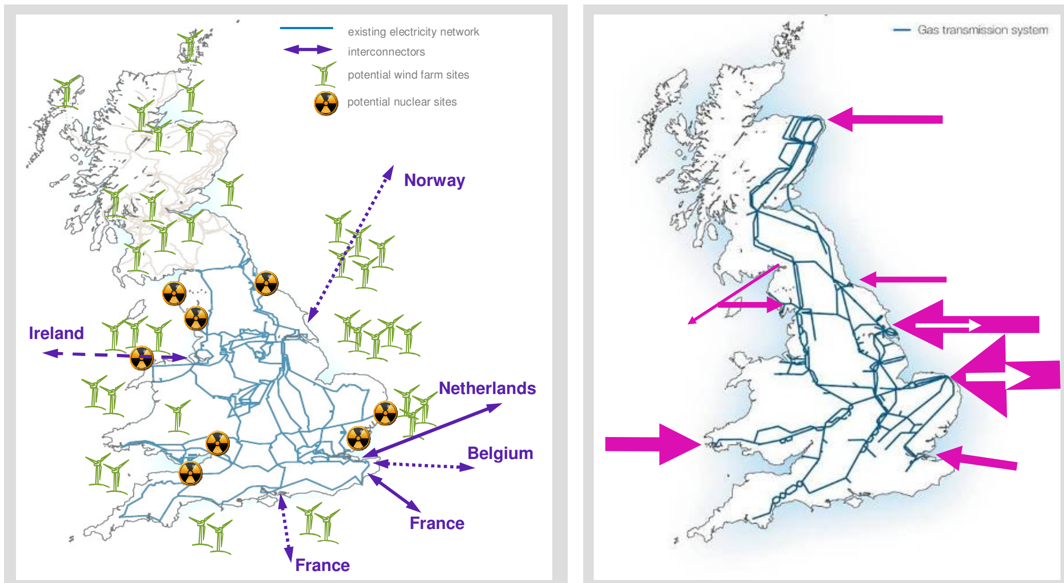

Between now and 2020 electricity and gas transmission networks require significant investment in order to facilitate the changing power generation mix and the transition to a higher renewable, lower carbon energy future.

Historic norms of north to south power flows will no longer prove true. Future power generation and gas supply sources will be located with greater geographical diversity, and will exhibit greater variance in time.

New nuclear and wind power generation and new electricity interconnectors will all be located at diverse costal locations around the UK, and will have significantly different characteristics than in the existing generation mix. The electricity network will therefore need significant investment in connection and reinforcement to accommodate these new sources of energy.

Varying gas importation from continental and LNG sources will necessitate investment to ensure the gas transmission network has the required flexibility to manage new east-west, west-east and south-north flow patterns.

Transmission networks are a key facilitator of the transition to a low carbon economy, and investment is critical to ensure the UK is able to met it’s carbon and renewable energy targets.

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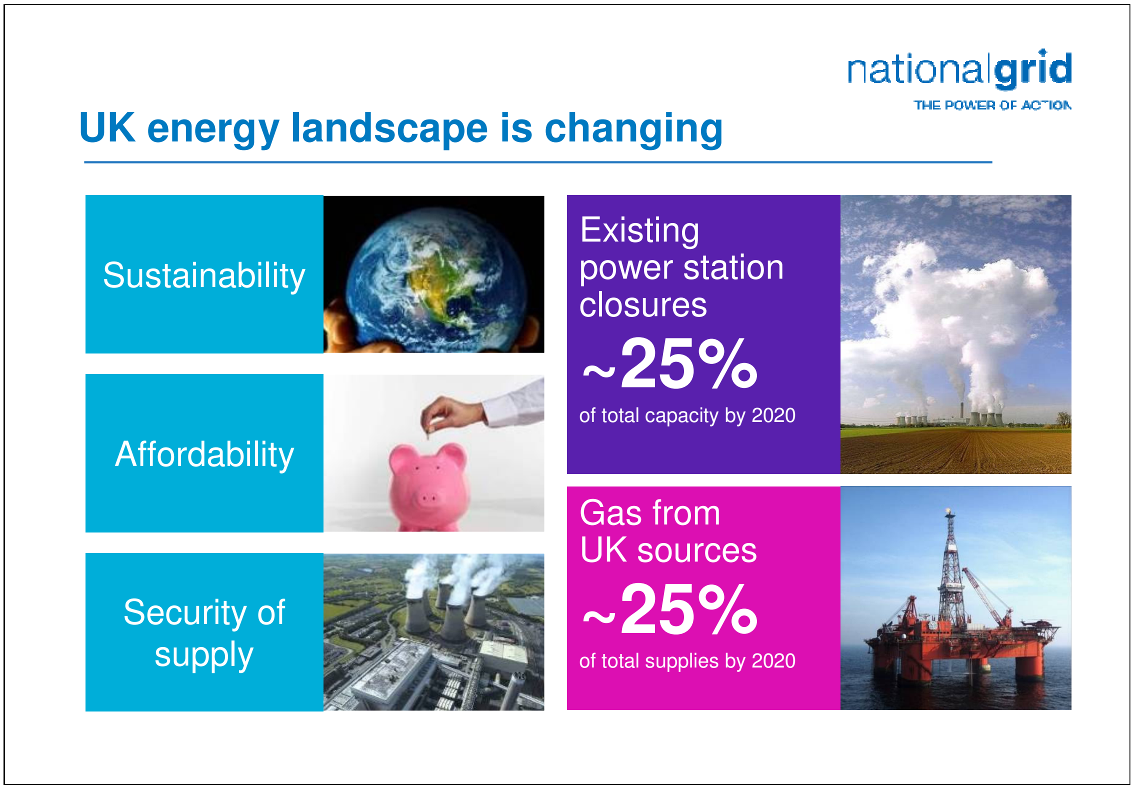
The Future Demand and Generation Mix

Duncan Rimmer
Future Transmission Networks

Transporting Britain's Energy – 14th July 2011



UK energy landscape is changing:

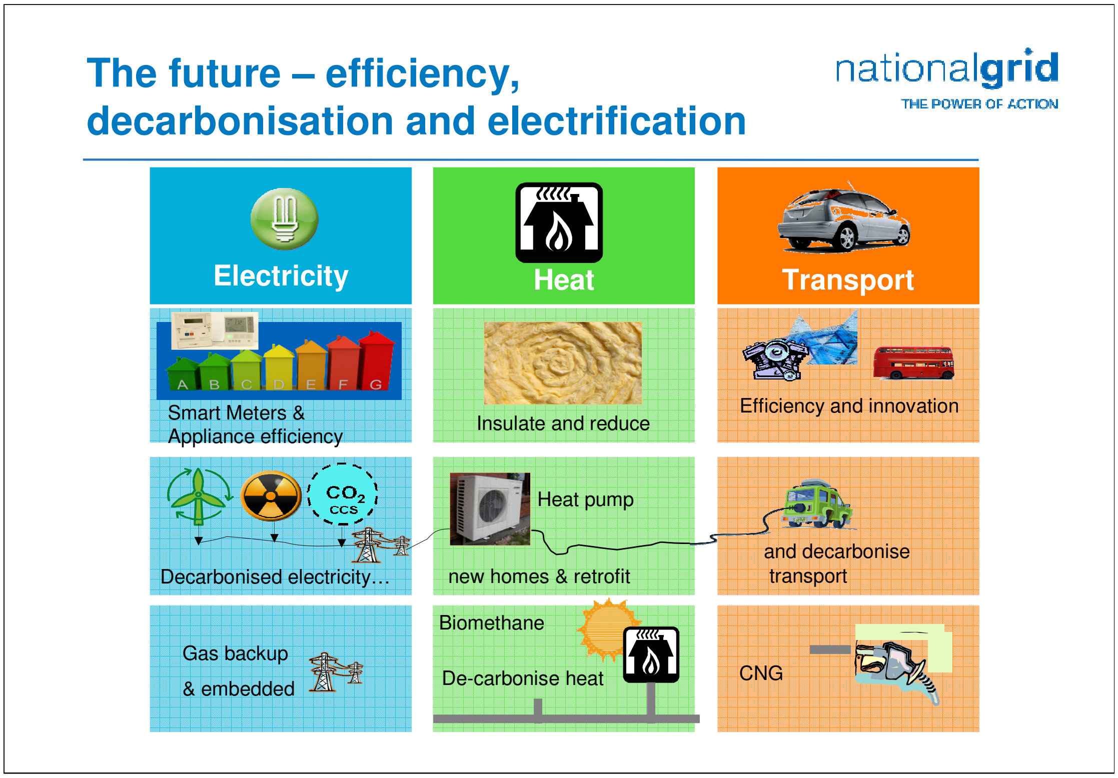
-With a policy backdrop of sustainability, affordability and security/diversity of supply the UK is facing significant change in its energy supply over the next decade.

-Around 25% of existing generation plants are due to close due to environmental legislation (LCPD) and age. If the impact of the Industrial Emissions Directive (IED) is also allowed for this figure rises to around 33% by 2025.

-And during the period to 2020 when we are constructing several new CCGTs our indigenous gas supplies are falling and will reach a level of only 25% by 2020.

-While this appears, on the face of it, a major challenge it could also be viewed as a great opportunity to move to a lower carbon future by replacing this plant with low carbon generation.

-However, there is no silver bullet and this low carbon generation will need to include renewables, nuclear and fossil fuels with carbon capture and storage (CCS) not to mention the networks to deliver them.



The future – efficiency, decarbonisation and electrification:

The future will have a wide range of potential pathways to 2020 and beyond that will result in different trajectories to renewable and GHG emissions targets. Not all of these pathways will achieve the targets in the time specified but all will move towards the targets supported by a range of incentives.

Analysis can be undertaken by looking at the energy market splits for electricity, heat and transport and how future pathways may develop.

- energy efficiency (the most cost effective way of moving towards the targets)

- Decarbonisation of electricity, then allows the decarbonisation of heat and then transport

- Gas still has an important role to play as traditional heat then progressively moving to roles as back up for wind, peak heating, renewable gas as biomethane and CNG for transport e.g. lorries which can't be realistically electrified.

Key electricity demand drivers

- Energy efficiency measures
- Growth in households and appliances
- Electricity price
- Rate of heat decarbonisation
  - Switch to heat pumps
- Rate of transport decarbonisation
- Growth in micro & embedded generation
  - Incentives e.g. FiTs, ROCs

Key electricity demand drivers:

There are a number of key variables that can affect the pathway of future demand levels.

-Energy efficiency supported by Government initiatives, e.g. the Green Deal, will support reducing demand particularly when coupled with growing fuel prices.

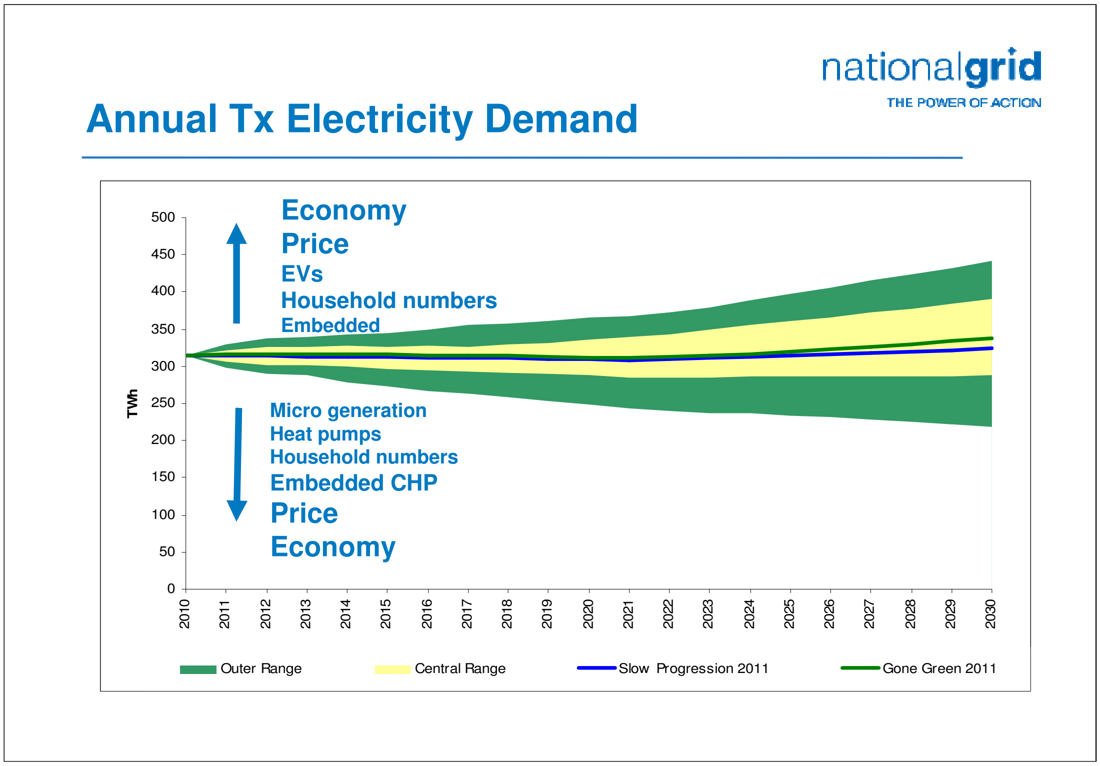
-This will be counter acted by growth in the economy and from new households and appliance numbers in the home.

-To achieve the renewable heat levels required (~12% by 2020) we need to see heating moving from fossil fuels (notably oil) to renewable heat from biomass, ground and air source heat pumps. However, while heat pumps are well suited to new properties there are limitations to retrofitting heat pumps into old 3 and 4 bed roomed homes where the heat requirement during the colder winter months is significantly higher than the warmer winter months and consequently would be not be cost effective to meet by building powers station to operate for 2 to 3 months a year. Hence this “peak heating” is best met with a hybrid approach with heat pumps providing the base load with the peak heat being met from initially natural gas and they eventually biomethane.

-We have assumed the RHI will support both heat pumps and biomethane injection making this hybrid model (which many of us have in our homes today incorporating a gas boiler and electric heaters) a cost effective solution for end consumers and UK plc.

-While virtually all long term scenarios, that achieve the targets, have significant electrification of transport the real uncertainty is when will EVs become commercially viable. We have assumed this occurs in the 2020s.

-Finally the growth in micro generation supported by Feed in Tariffs (FiTs) and small & medium embedded generation supported by ROCs will limit the growth in demand from the transmission system.



Future electricity demand ranges:

- The two scenarios Slow Progression and Gone Green have very similar demand levels until post 2020 when the impact of the electrification of heat and transport start to accelerate in Gone Green.
- A number of sensitivities have been developed around these scenarios to illustrate a range of potential demand scenarios for the future. Sensitivities modelled here include: fuel prices, energy conservation, household numbers, power generation capacity and output, combined heat and power (CHP) capacity, embedded generation and exports.
- the chart also shows an outer fan (illustrating a simple summation of all sensitivities) and an inner fan illustrating combinations of sensitivities more likely to occur together. For example, the highest levels of demand shown are likely to be reached only if the relevant factors (such as the rate of economic growth, or the take-up of electric vehicles) were all stimulating demand growth and no factors were acting to reduce demand. In practice it is extremely unlikely that they would all combine to push electricity demand in one direction. A narrower central range of more probable demand levels has therefore been highlighted on the chart. However, even within this range, there are still significant variations.

Power Generation Scenarios

- What level of renewable/low carbon generation will be required to meet the environmental targets?
- How many stations will close due to LCPD and IED?
- Life extensions for nuclear plant and timing of new nuclear?
- How much non renewable plant required to maintain adequate plant margins?
- Relative fuel prices, capital costs, incentives and operating patterns of different types of existing and new generation
- Demonstration to deployment for CCS?
- Four scenarios developed as part of Offshore Development Information Statement
  - One that achieves the renewable target late ~2026
  - One that achieves the target in 2020
  - Two that achieve it early ~2017/18

Power Generation Scenarios:

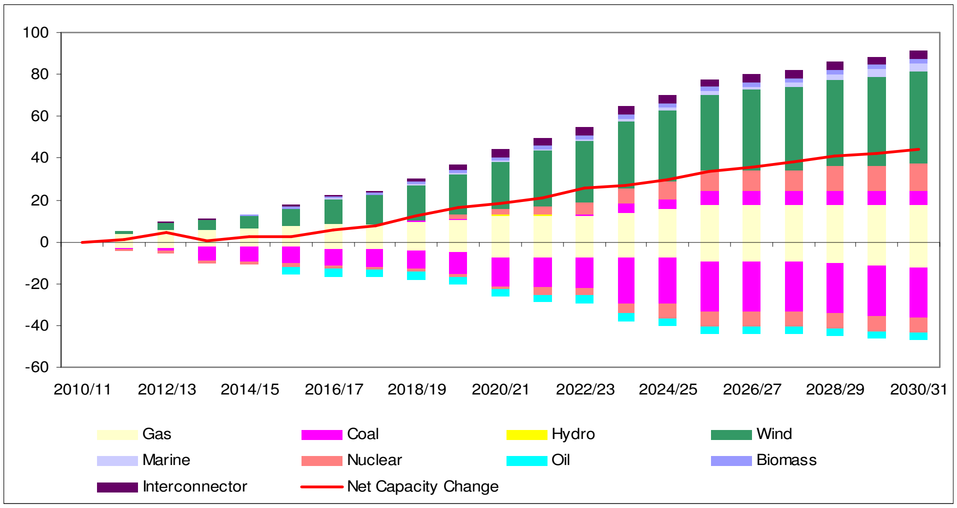
-A number of key areas are assessed when producing the transmission generation background which will vary depending on the scenario being developed.

Scenario Development:

-As part of our Offshore Development Information Statement consultation process we developed 4 scenarios; Slow Progression, Gone Green, Sustainable Growth and accelerated Growth.

-However, due to the lack of time and for clarity of message we will concentrate on two of these scenarios Gone Green that achieves the target on time and Slow Progression that moves towards the target, supported by Government incentives, achieving it around 2026.

Generation mix changes – Gone Green



A summary of Gone Green's key points:

-Overall in Gone Green we see 47GW of plant closing by 2030 with 91GW opening giving a net increase in gross capacity of 44GW.This increase allows for higher demands and the intermittency/lower availability of wind while maintaining an adequate level of plant margin.

Detail by plant type:

-AGR nuclear plant receive additional five-year life extensions i.e. giving 10 years in total;

-First new nuclear plant connects in 2019/20;

-Significant amount of coal plant closes due to IED and age;

-4GW of coal with CCS connects post 2023 in addition to the development of CCS at original demonstration site;

-Existing gas-fired plant assumed to close at around 25 years of age;

-A total of 19GW of new gas-fired generation connects over the period with 7GW already under construction / commissioning;

-7GW of new gas plant with CCS is included in the scenario from 2023;

-The build-up of wind generation reaches nearly 26GW of wind capacity in 2020 (16.5GW offshore) and 47GW (nearly 37GW offshore) in 2030;

-Marine generation develops more quickly than in the Slow Progression scenario reaching 4GW in 2030.

-Note that if wind was de rated to 5% then the net capacity change would show minimal change.

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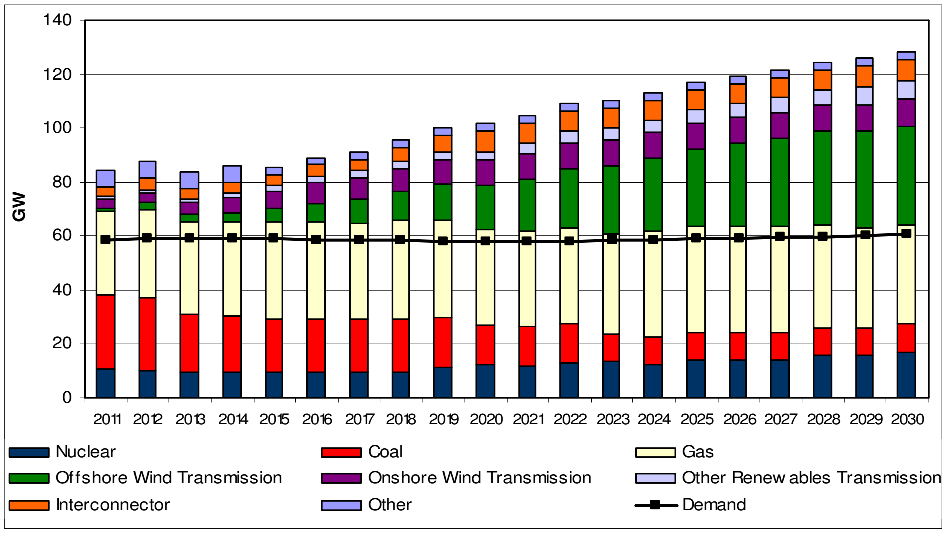
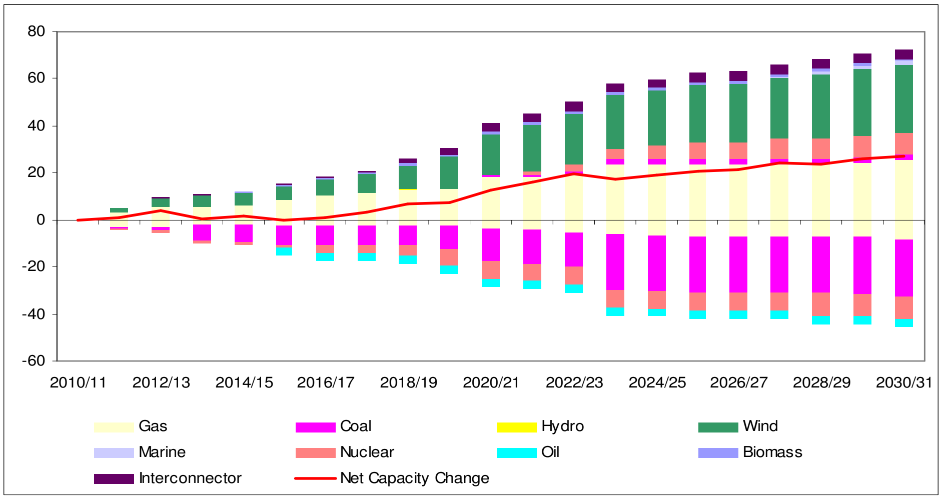
Generation mix – Gone Green



Overall Generation Mix:

Overall capacity grows to 128GW from 85GW today (transmission) to provide the necessary plant margin to cover slightly higher peak demand levels as we assume most electric cars would be charged over night.

Generation mix changes – Slow Progression



A summary of Slow Progression's key points:

-Overall in Slow Progression we see 44GW of plant closing by 2030 with around 69GW opening giving a net increase in gross capacity of 25GW.This increases allows for the intermittency/lower availability of wind while maintaining an adequate level of plant margin.

Detail by plant type:

-AGR nuclear plants receive five-year life extensions unless otherwise announced;

-First new nuclear plant connects in 2021/22;

-A significant amount of existing coal plant closes by 2023 due to a combination of the IED and the age of the plant;

-CCS is retro-fitted at one coal plant as part of the government funded scheme with no further CCS coal plant included in the scenario over the study period;

-Existing gas-fired plant remains open for longer than in the Gone Green scenario;

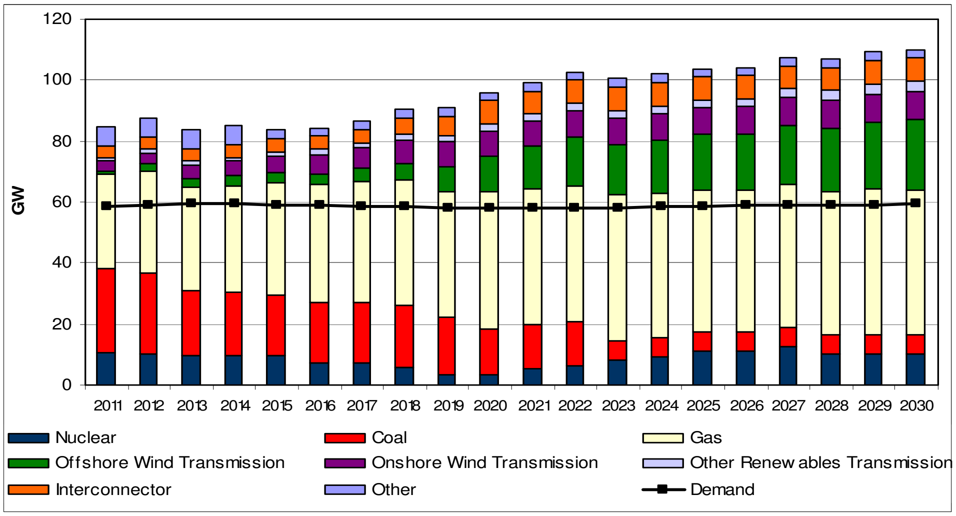
-A total of 26GW of new gas plant is included in the scenario by 2030, with 7GW already under construction / commissioning;

-6GW of new gas plant with CCS is included in the scenario;

-The build-up of wind generation is lower in this scenario with 20GW of wind capacity in 2020 (11GW offshore) and 32GW (23GW offshore) in 2030;

-Marine generation is assumed to develop very slowly with some larger scale generation not connecting until around 2027.

Generation mix – Slow Progression



Overall Generation Mix:

Overall capacity grows to 110GW from 85GW today (transmission) to provide the necessary plant margin to cover similar demand levels.

The capacity figure is less than Gone Green as less renewable is connected and more gas while demand is at similar levels to Gone Green until post 2020 when the growth in heat pumps pushes Gone Green higher.

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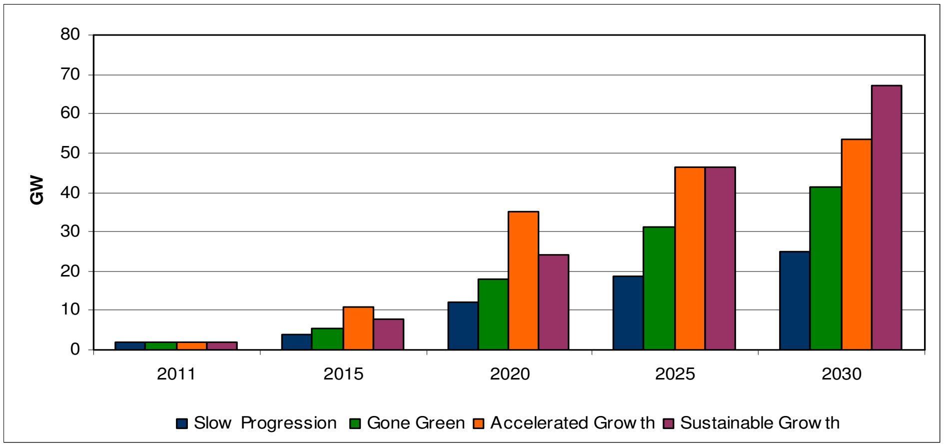
Renewable - offshore scenarios

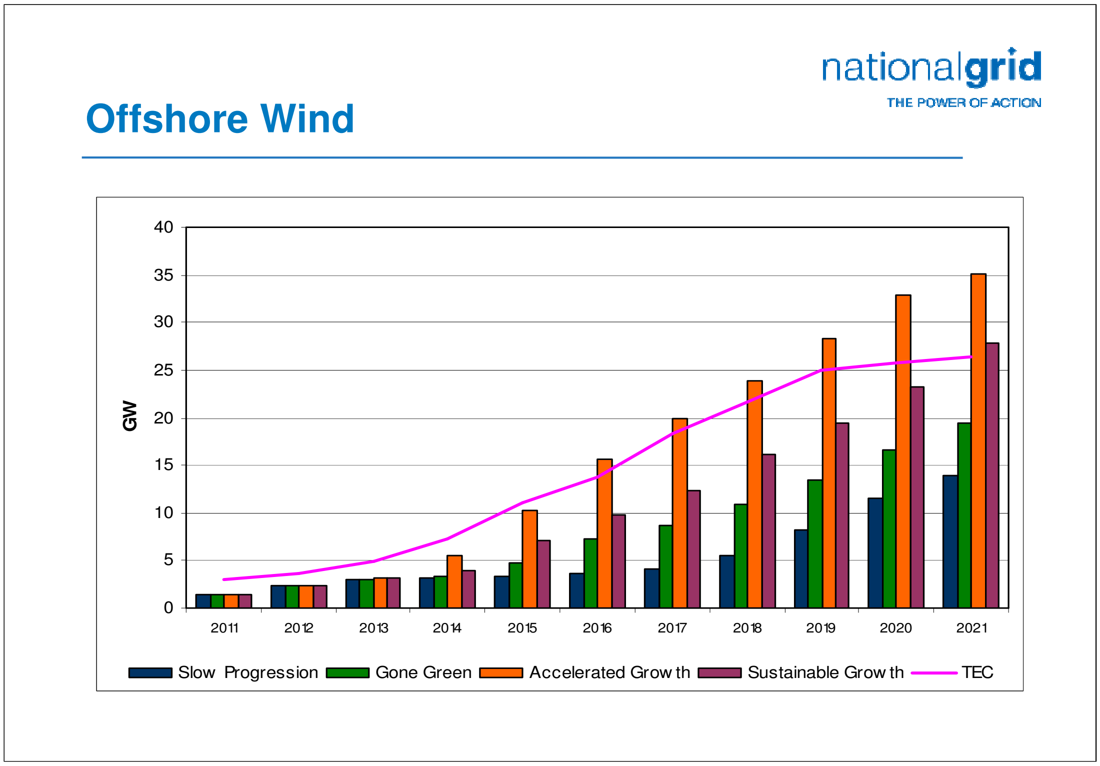


Growth in Offshore Wind/Marine:

-To achieve the environmental targets a large proportion of energy will need to come from offshore renewables and offshore wind in particular.

-As part our industry consultation to develop the scenarios utilised in the Offshore Development Information Statement (ODIS) four scenarios were agreed which gave a wide range of potential development.

-The assumed build up in offshore generation ranging from 12GW to 35GW in 2020 to 25GW to 67GW in 2030.



Growth in Offshore Wind:

How do the scenarios compare to what has actually signed up for a connection. This shows that more than enough offshore wind has signed up to meet Gone Green so it is now a case of how much will be built and when. Note that for Round 1 virtually all the sites announced by the Crown Estates has led to a connection. However, as any financial advisor will say “past performance is no indication of future performance”.

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Key generation uncertainties

- Incentives existing and new (EMR)?
- Capital costs, fuel and carbon prices?
- Commercialisation of CCS followed by deployment?
- Planning issues for all new generation and associated networks
- Offshore connections radial or integrated?
- European super grids?
- **If delayed then gas is the only option!**

Key Generation Uncertainties:

These can be split into two main categories; market based uncertainties and delivery based uncertainties.

Market Based:

-Will incentives change or will new ones come along to ensure targets are met?

-Will capital costs for renewable, nuclear and CCS generation become commercial?

-EU carbon price and or international agreement on Climate Change action i.e. a new Kyoto?

Delivery Based:

-Will planning issues be sorted so they aren't a barrier?

-Can the offshore regime be developed in a cost effective and practical manner through more integration?

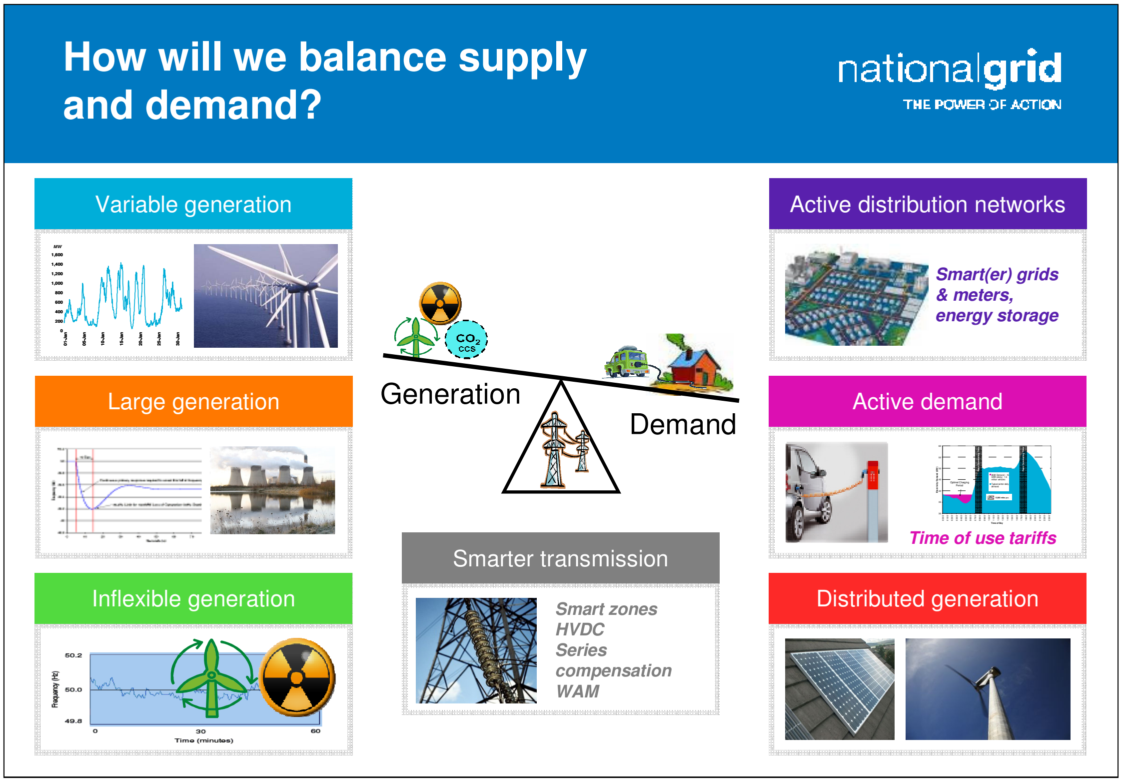
-How will European networks grow following legislation and will we see the start of much greater interconnection and co-ordination?

If any of these slip then gas will be the only large scale option to fill the gap.

Impact of Wind Intermittency

Gary Dolphin
Future Transmission Networks

Transporting Britain's Energy – 14th July 2011



The way National Grid balances the electricity network is changing.

The coming decade will see major changes in the way electricity is generated in the UK, from the continuing growth of wind generation, with its variable output, to the prospect of new and larger nuclear power stations that are inflexible in their output.

In addition demand will also be changing. By 2020, new technologies such as electric cars, heat pumps and smart meters will be in the early stages of changing the way electricity is consumed.

These balancing challenges can be met through a combination of adapting the way the company operates the transmission system and developing the way it uses both new and traditional "balancing services" procured from the energy market. The transmission network is already smart, with the control system constantly monitoring the performance of substations, switches, lines and transformers, but in the future it will need to be smarter, with the deployment of various smart technologies.

Further information on the likely issues relating to operating the electricity transmission networks in 2020 is available in a consultation document issued in June 2011, which is available at the following link:

www.nationalgrid.com/uk/Electricity/Operating+in+2020/

2010 Gas power station loadfactor

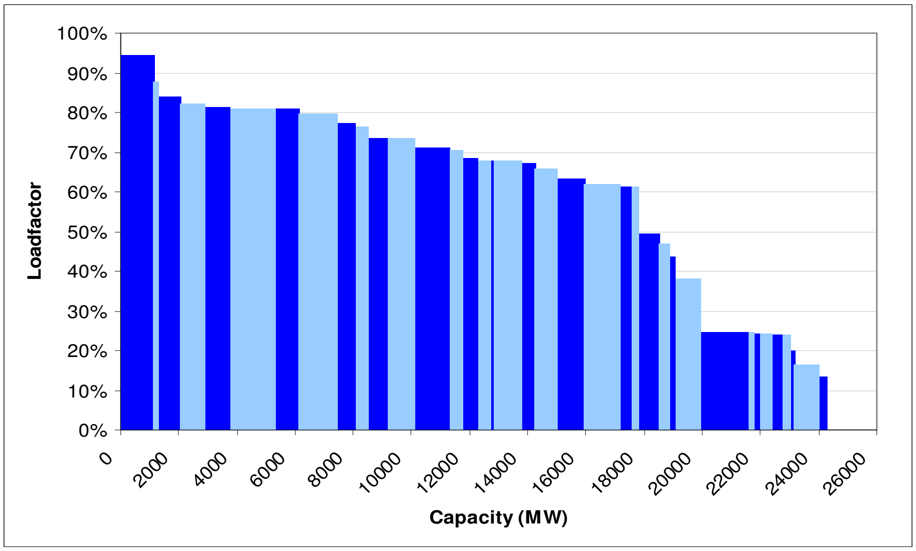
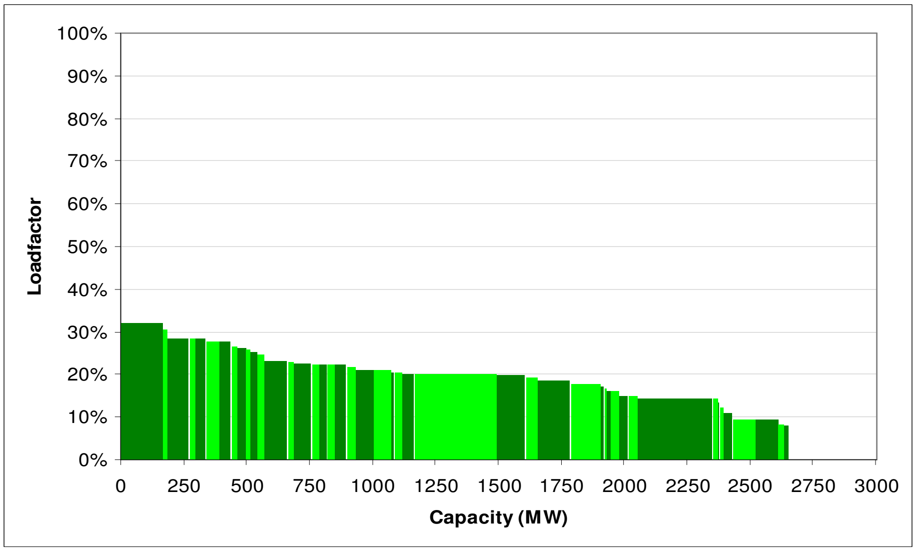


Chart shows actual annual calendar year loadfactors for the majority of gas fired power stations. Note that the chart does not show all gas fired plant, as those that started generating mid year, or those on long term maintenance are not included.

There is a wide range of annual loadfactors, but with the majority of plant operating in the 60% to 80% annual loadfactor range.

Chart shows roughly 25GW of gas fired plant.

2010 Wind farm loadfactor



Annual loadfactor ranges from 30% to 10%

Chart shows roughly 2.6GW of wind generation (total GB wind capacity for 2010 is approximately 5GW)

2010 Coal power station loadfactor

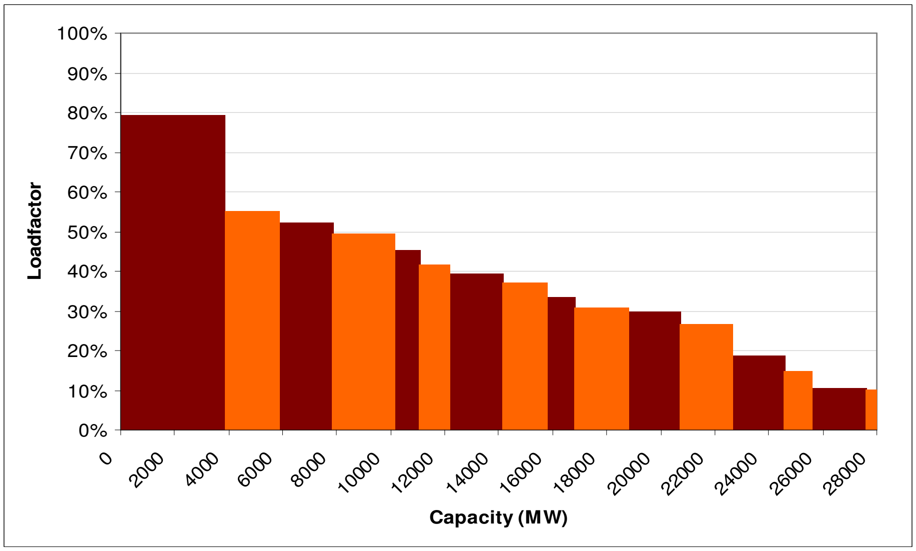


Chart shows wide range of loadfactors for coal fired plant ranging from 80% to 10%

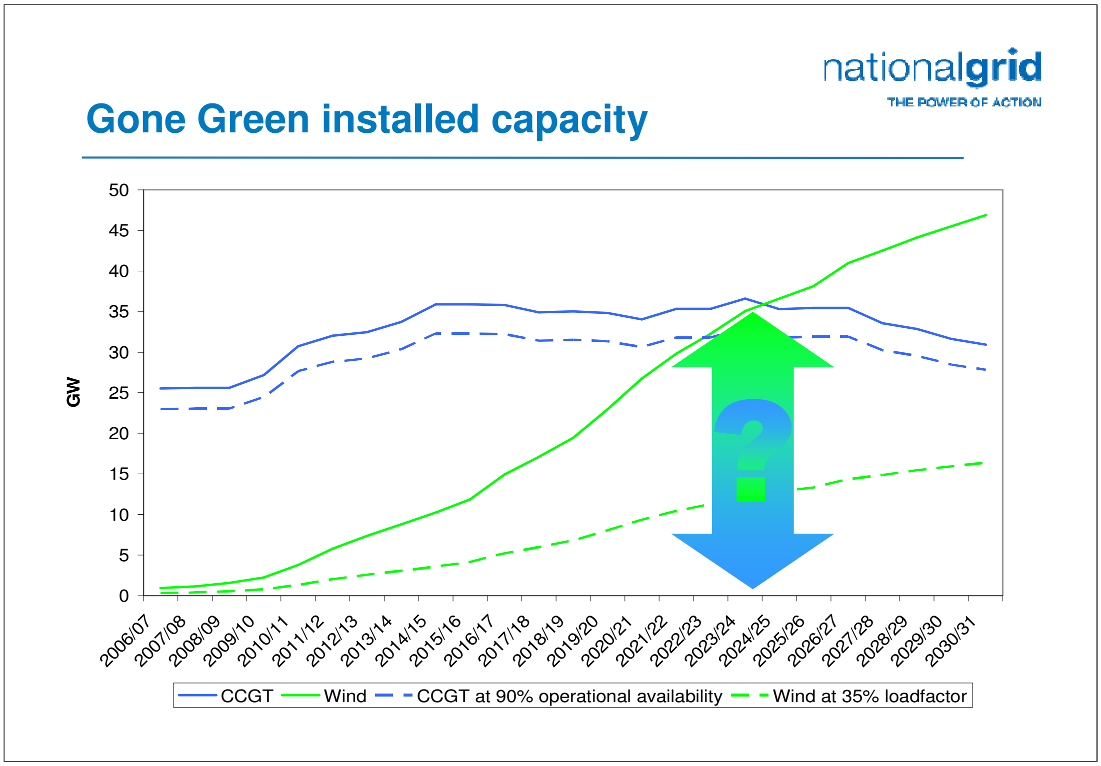


Chart shows CCGT (combined cycle gas turbine) and wind installed capacity, both actuals and future levels under our Gone Green scenario.

Dotted blue line shows operational availability for CCGTs at 90%; a previous slide shows that annual loadfactors for CCGTs in 2010 were in the region of 60% to 80%.

Dotted green line shows annual loadfactor for wind generation, assumed at 35%. 35% is reflective of the assumption that there will be considerable offshore wind farms where higher loadfactors will be experienced, as well as a very geographically diverse wind generation fleet.

By 2024/25, the scenario shows similar levels of CCGT and wind capacity. Due to wind intermittency, there will be days where wind loadfactor may be considerably higher or lower than 35%. The intermittent nature of wind generation will require considerable flexibility from other generation sources, assumed to be primarily gas fired generation. Hence wind intermittency is likely to have a significant impact on CCGT gas demand. The following slides show the results of analysis undertaken by National Grid to quantify the impact of wind intermittency on the gas network.

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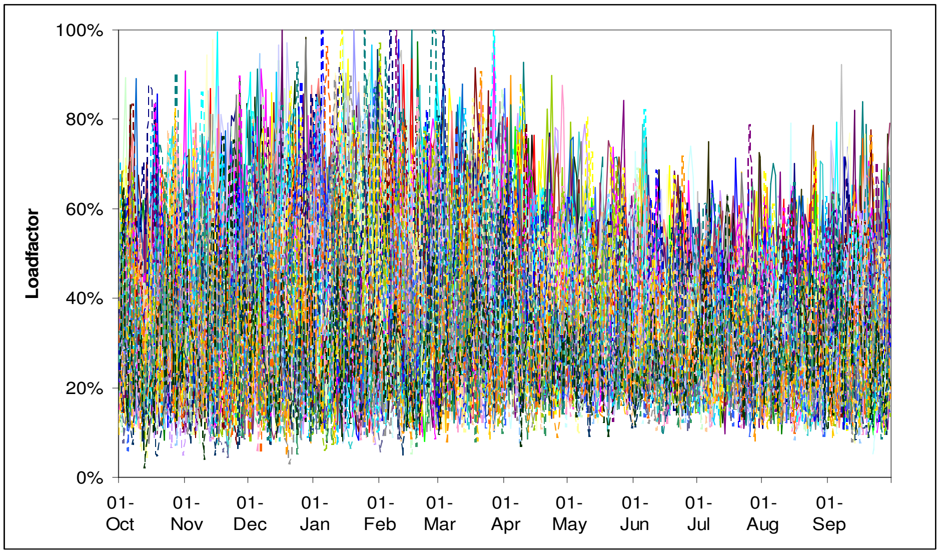
82 year daily wind loadfactor



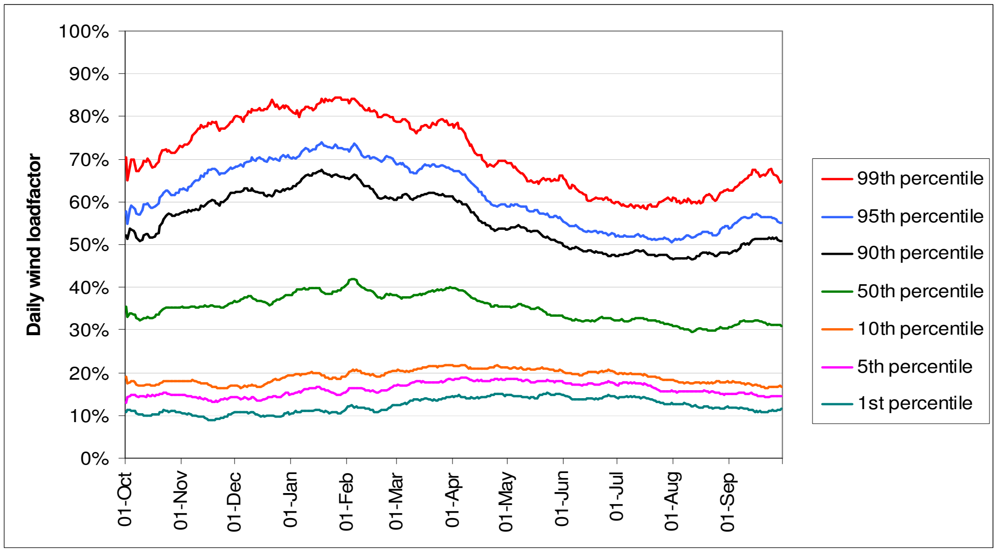
82 years (1928/29 to 2009/10) of daily wind loadfactor data.

Considerable daily variation from year to year, as well as day to day volatility.

Shows some seasonality.

Daily wind loadfactor percentiles

82 year data set - 15 day rolling average



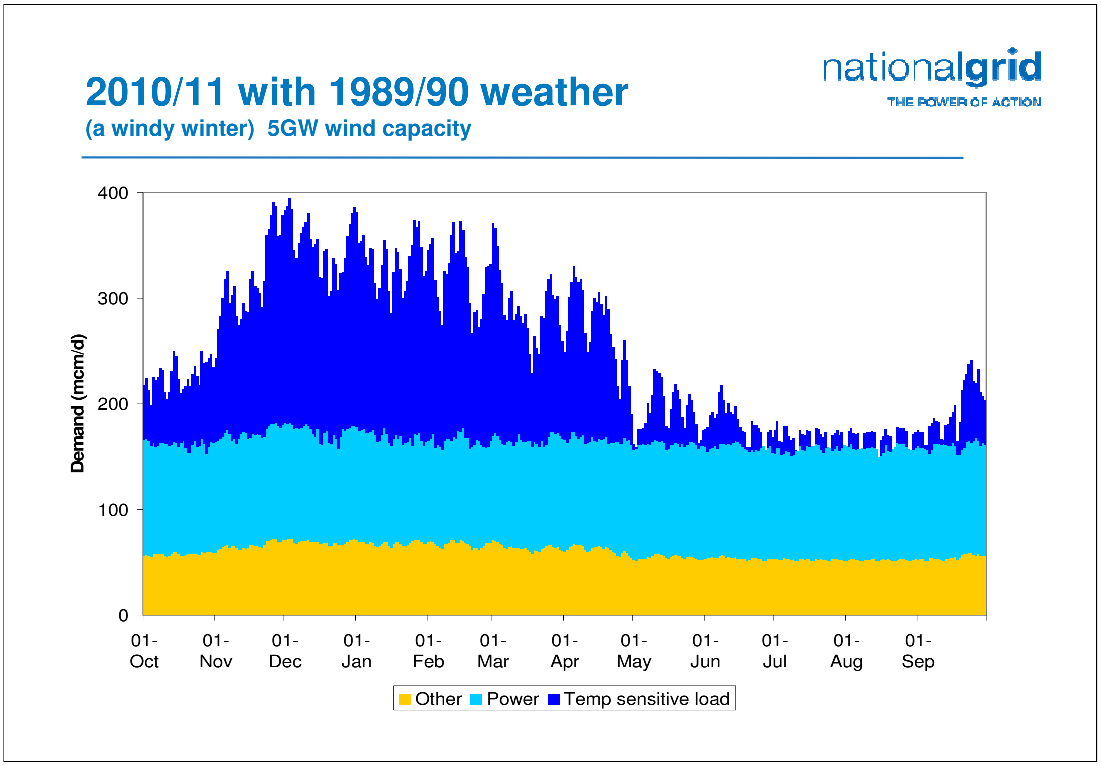
By looking at various percentiles for each date, the seasonality becomes clear.

The average for each day is in the 30% to 40% loadfactor range.

The 95th percentile – as high as 70% during the winter months, ie for 5% of the time the daily wind loadfactor could be 70% or higher.

Conversely, the 5th percentile – as low as 15%, ie for 5% of the time the daily loadfactor could be 15% or lower

Note that this dataset has been adjusted to reflect the potential for significant levels of offshore wind generation for the UK. Hence the average annual loadfactor is approximately 35%. The dataset has also been adjusted for the potential loss of wind generation due to high windspeeds.



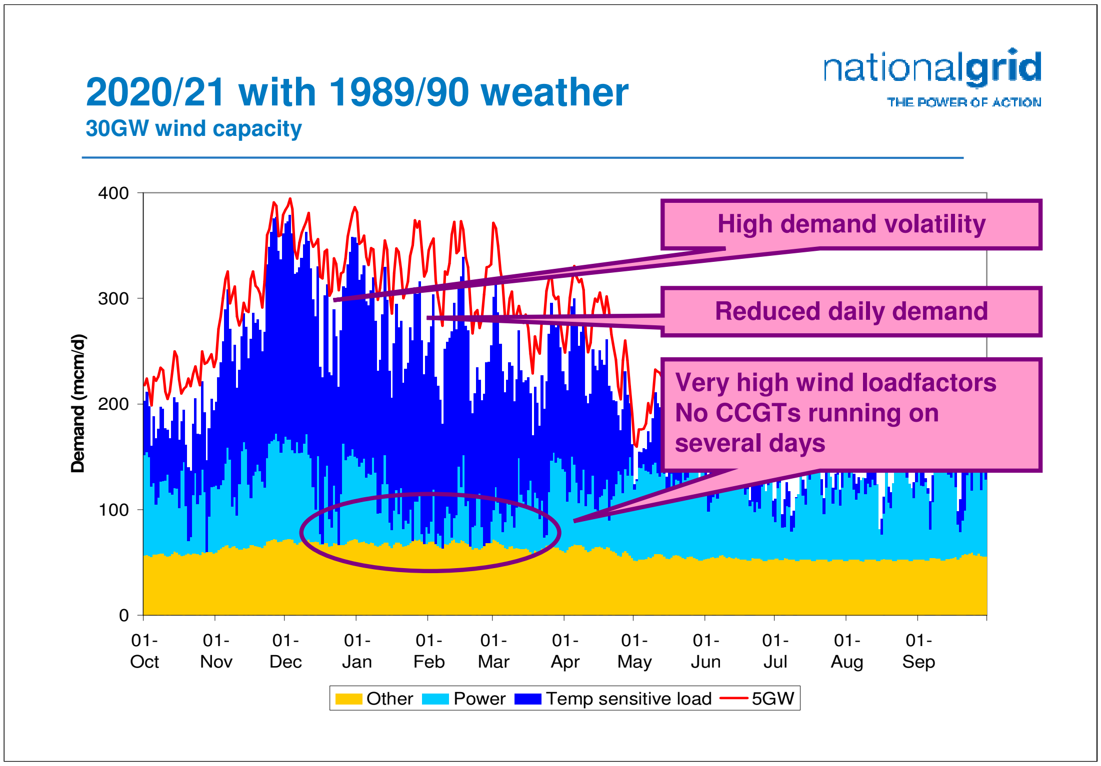
The chart is the output from a model that uses 82 years of national daily temperature and wind speed data. It models potential variation in CCGT demand due to wind volatility.

Gas demand modelled in three load types: temperature sensitive load (ie predominantly domestic); power generation load (ie CCGT); and other (ie industrial and commercial).

It does not model daily electricity generation mix, but at a high level CCGT power generation is modelled at base load, subject to wind taking precedent. The model assumes that CCGTs provide all backup for wind intermittency. The model has been validated by checking output against actuals for 2009/10.

Note that 2010/11 modelled with 1989/90 weather results in a not particularly cold winter – no demand days above 400 mcm/d.

For 2010/11, with only 5 GW of wind capacity, wind intermittency has little impact on gas demand for CCGTs.



The slide shows gas demand in 2020/21 with 1989/90 weather. The scenario assumes 30 GW of wind generation, hence wind intermittency has a significant impact on the level of gas demand.

The chart shows:

•Increased demand / supply volatility and many high day to day demand changes

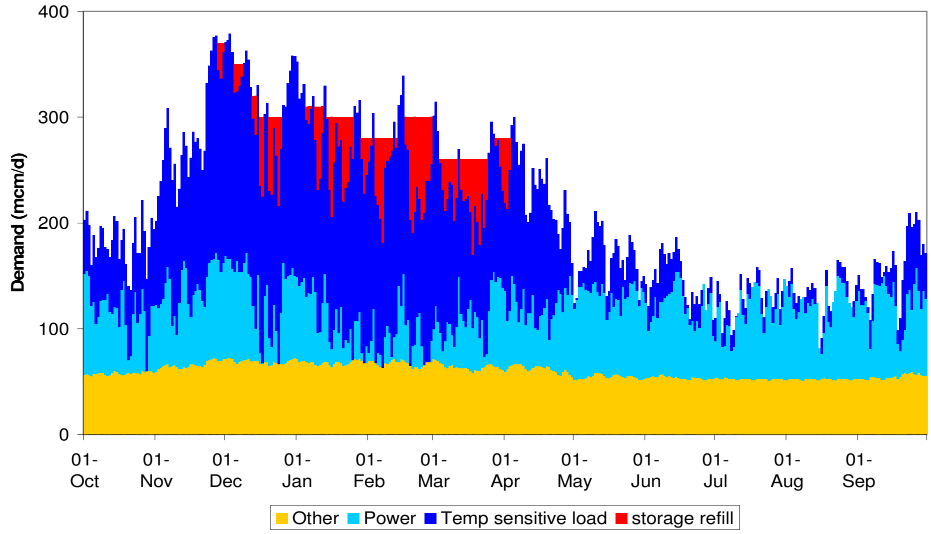
•Lower demand in general, as significant levels of wind generation result in reduced CCGT gas demand

•Lower peaks for most of the time, as there is usually some wind generation

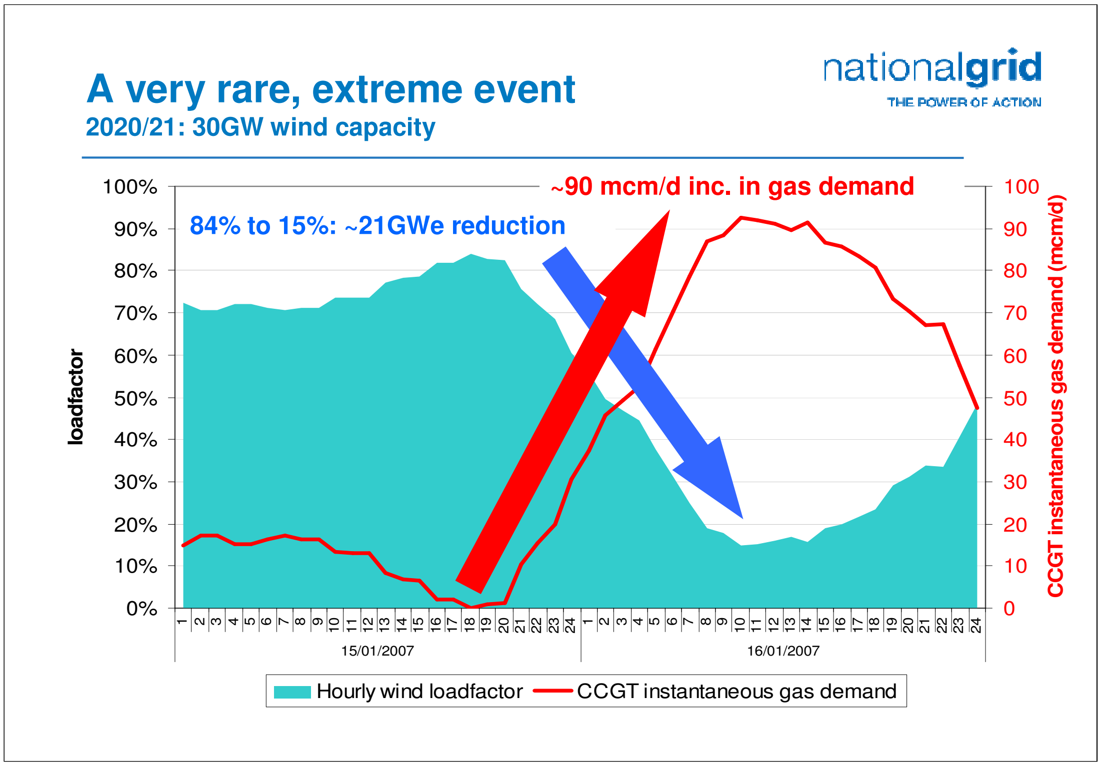
•During the period January to March there are times when wind loadfactors are very high and the resultant CCGT gas demand is very low and on certain days even zero, i.e. no generation is required from any CCGT.

The increased demand volatility is likely to provide opportunities for flexible rather than seasonal supply.

2020/21: more storage refill opportunities



The chart illustrates that the increase in demand volatility may enable more storage injection.



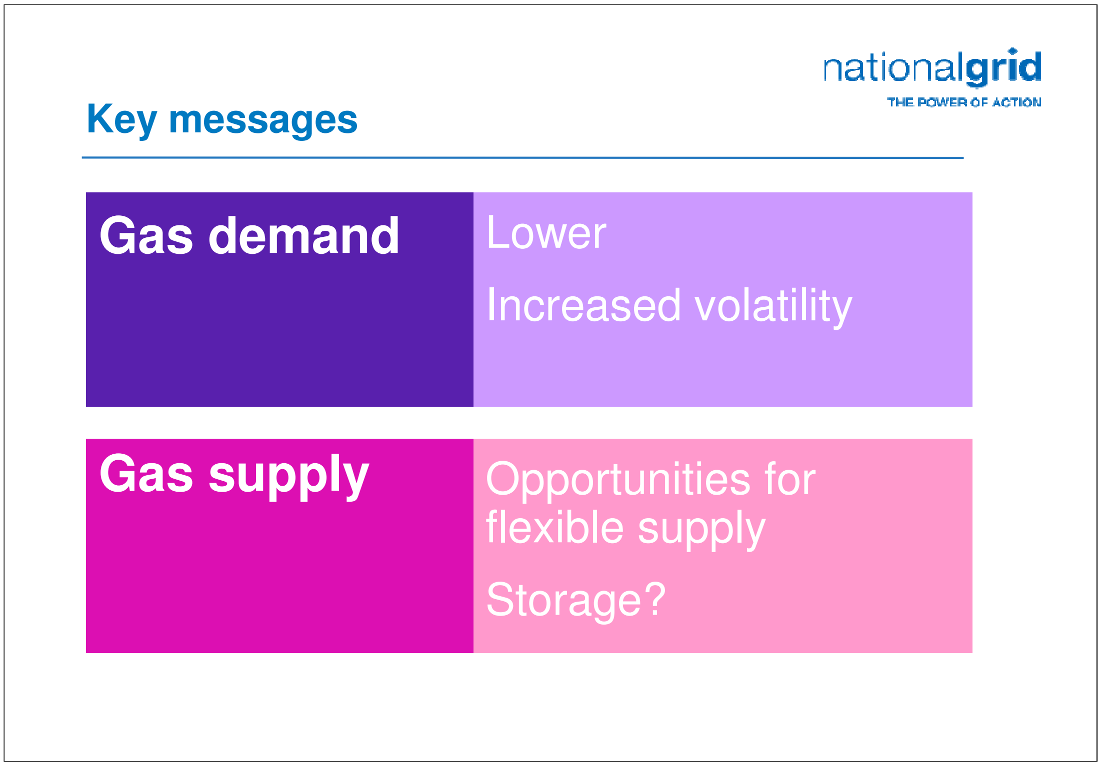
The chart shows a rare, extreme level of within day wind loadfactor change. Over a period of approximately 15 hours, wind loadfactor decreases from 84% to 15%. Assuming total wind generation capacity is 30GW, this equates to a reduction in generation of approximately 21GWe.

If we assume all the reduction is made up by an increase in generation from CCGTs, then this equates to an increase in instantaneous gas demand of roughly 90 mcm/d.

This high level analysis makes no attempt to model within day electricity demand profiles: it simply provides a highly level metric for the scale of changes in gas demand that may be experienced with high levels of wind generation available.

In the years leading up to 2020, the range of uncertainty in which National Grid operates will increase significantly as a larger proportion of generation scheduling becomes a function of dynamic weather systems, and the more predictable demand led scheduling of generation diminishes. Hence new tools and processes will need to be developed to assist in managing the risk around supply and demand balance.

National Grid expects to further improve forecast accuracy of wind generation. It is expected that wind output deviation from forecast over 4 hours will reduce from 50% currently to around 30% by 2020 through improved wind forecasting models.



Gas demand

The analysis shows that as wind generation capacity increases, gas demand will on average be lower as generation from windfarms displaces gas fired power generation.

In addition gas demand shows increased volatility, as gas fired power stations provide backup to wind generation.

Gas supply

Increased gas demand volatility leads to increased supply volatility, providing opportunities for flexible supplies.

Also greater day to day variations in demand may provide greater opportunities for storage recycling.

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2011 Demand Scenarios and Supply Forecasts

Peter Parsons
Future Transmission Networks

Transporting Britain's Energy – 14th July 2011

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Structure

- **Demand Scenarios**
  - **Gone Green**
  - Depicts plausible energy mix which will meet 2020 environmental targets: **'15% of energy from renewables'**
  - **Slow Progression**
  - Slow Progression towards renewable and carbon emission reduction targets
  - New technologies develop more slowly, policies and incentives do not have required / expected impact?
- **Supply Forecasts**
- **Network Flex / Design**

Gone Green reflects existing and previous government policies.

Gone Green also meets EU targets for the UK.

Slow Progression meets 2020 environmental targets post 2025 but before 2030. (GG has 29% renewable electricity in 2025, target approximately 31%).

Gone Green is therefore more about meeting energy targets through renewables and low carbon emissions rather than a scenario driven by energy prices.

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Demand Assumptions

	Uncertainty	2011	2020 Slow Progression	2020 Gone Green
	New nuclear	Locations announced	2021	2019
	Existing nuclear	7 GW to close by 2020 without further extensions	5 year extension 7 GW to close by 2020	10 year extension 1.5 GW to close by 2020
	CCGT + CHP (Tx)	30 GW 5 GW under con.	17.5 GW new 44 GW Total	11.5 GW new UC 35 GW Total
CO_2	CCS	Studies	Demo only Coal CCS in GG post 2020	
	Wind (Tx & Dx)	5.5 GW	22 GW	28 GW
	Electric vehicles	~2,000	0.7m	1.7m
	Heat pumps	~50,000	0.8m	1.2m

Future power generation assumptions provide the greatest gas demand uncertainties.

Electric vehicles (EV) and heat pumps have (through to 2020) limited impact on gas demand but are important in meeting 2020 energy targets.

New nuclear plant connects sooner in the Gone Green scenario and has a slightly quicker build rate than in Slow Progression.

Existing nuclear plant receive longer life extensions in the GG scenario – this helps to maintain the level of nuclear capacity and ensures the UK remains on target to meet the carbon emissions reduction targets.

There is more new CCGT plant in the SP scenario principally due to the shorter lifespan assumed for the existing nuclear plant.

CCS demonstration plant is included in both scenarios, although in the SP scenario no coal plant with CCS is assumed. This results in further CCGT build post 2020.

As would be expected there is more wind and an increased build-up of wind in the GG scenario in order to meet the renewable targets.

One key uncertainty at the moment is the impact of Electricity Market Reform (EMR), the consultation covers four key aspects:

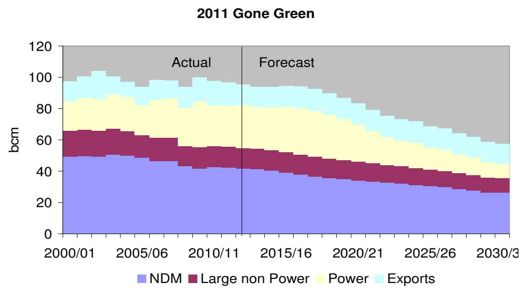
•Carbon floor price

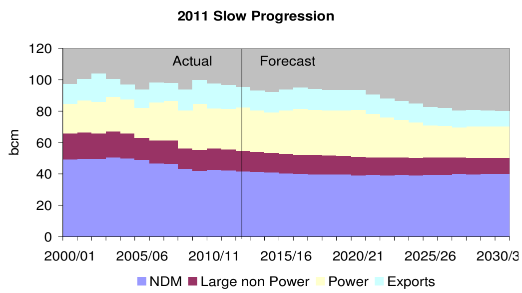
•Mechanism for subsidies – feed in tariffs / ROCS.

•Capacity payments

•Emissions Performance Standards

Annual Demand Forecasts





Basis for forecast trends:

- Non Daily Metered (NDM) lower due to energy efficiency (insulation & appliances), part offset by new houses and behavioural changes (SP only)
- Little change in large loads
- Power generation increases due to coal closure then falls as more wind is installed
- Exports reduce due to Corrib (~2012), higher exports to Continent in GG due to lower UK demand

Demands are broken down into just 4 sectors to enable comparison:

1. Non daily metered (NDM) demand is mainly domestic and small to medium sized commercial and industrial demand in the distribution networks (DNs). These demands are weather sensitive
2. Large loads are large commercial and industrial loads in the DNs and industrial loads on the NTS
3. Power generation is NTS connected loads only. Embedded power generation in the DNs is included in the large loads
4. Exports include those to Ireland and to Belgium

Gone Green NDM demand is lower than for Slow Progression due to the scenario emphasis of achieving lower carbon emissions, this is met through:

- Higher energy efficiencies
- New build houses have stricter building regulations
- A greater shift to more electricity heating

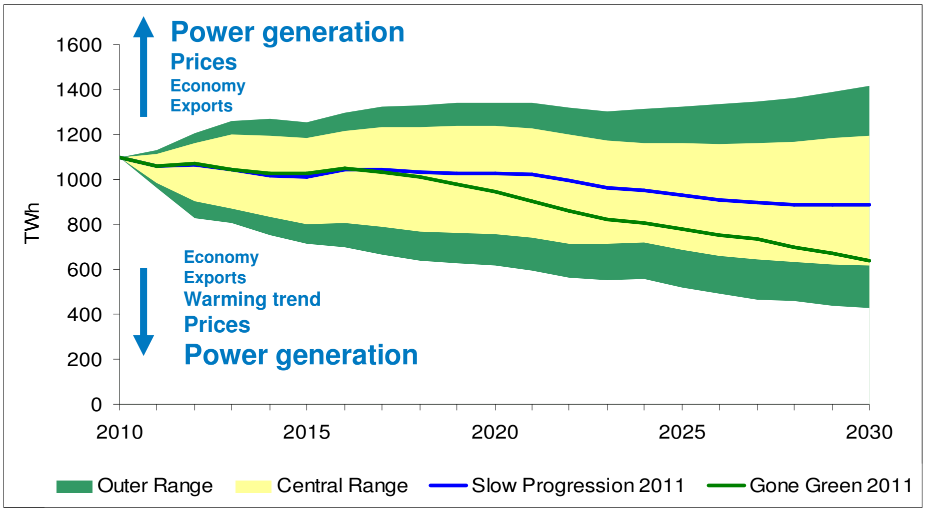
GG demand also follows the 10 year falling trend of lower NDM

Large loads are comparable in both scenarios, these are price sensitive

Power generation is lower in GG due to the assumptions of more wind to ensure lower carbon emissions

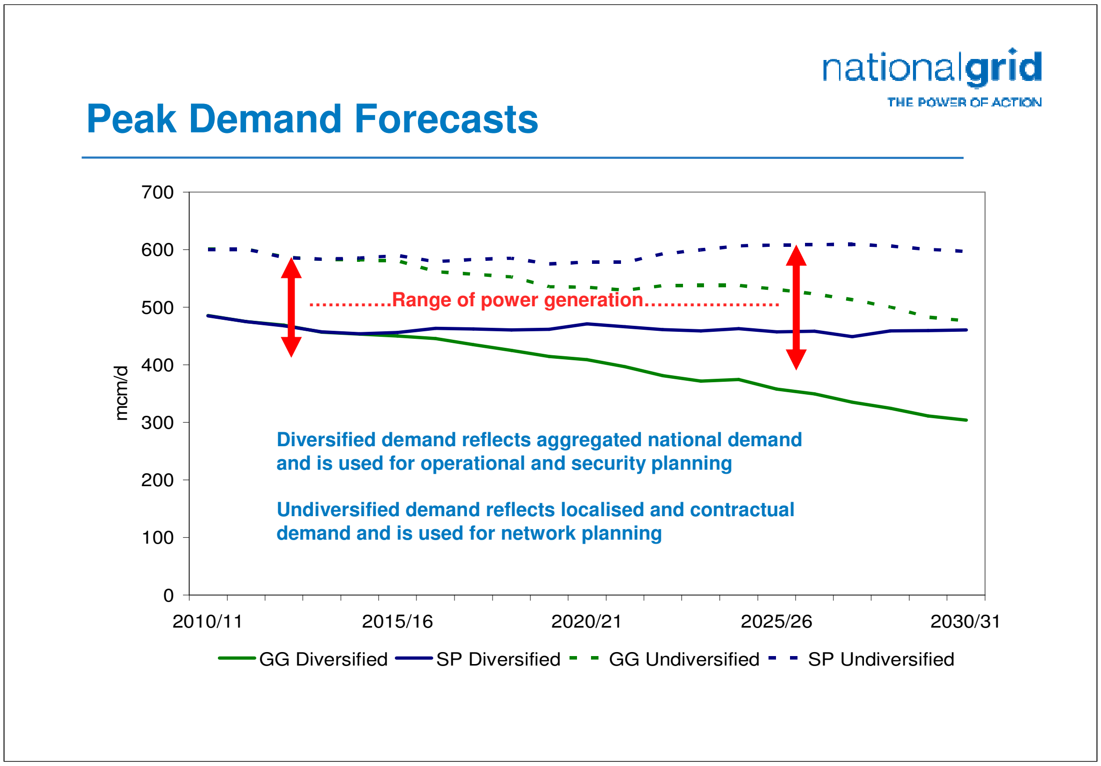
Assumptions for exports to Ireland are the same in both scenarios. Interconnector (IUK) exports are higher in GG due to lower UK demand

Forecast Range of Annual Demand



The ranges are based around Slow Progression. They also broadly reflect Gone Green as the biggest uncertainty is power generation which has limited down side and considerable upside in GG due to the scenario assumptions of high wind and low CCGT load factors

Price is identified as the second biggest influence. For SP price essentially determines power generation, hence price is the biggest influence. Price also determines UK exports (and imports) to the Continent



Peak demands are at 1 in 20 conditions

Diversified demands reflect aggregated national demands, they account for diversified weather patterns across the country and the expectation that not all contractual loads (notably power stations) will be operating at their maximum levels. Diversified demands are more reflective of actual demands and tend to be used for operational and security planning.

Undiversified demands account for simultaneous cold weather across the country and contractual loads operating at close to their maximum levels. Undiversified demands tend to be used for network planning to ensure there is sufficient capacity in a localised area.

Most diversity is in the largest loads notably power generation. A good example of this is for next winter, where the diversified power generation demand is due to high gas prices forecast at just 62 mcm/d compared to 158 mcm/d for undiversified demand. Gas demand for power generation could be much higher than the diversified of 62 mcm/d if for example the gas price reduced or there was a problem with the nuclear fleet etc.

Gone Green peak demands are lower than Slow Progression due to the assumptions behind GG. Namely, less CCGTs, energy efficiency measures, stricter building regulations for new build houses and a shift to more electricity heating.

The forecasts for peak demand are based on the current methodology and have not been modified for any concept of base load electricity heat and ‘peak’ heat from gas.

Basis for Supply Forecast

- Similar basis for Gone Green and Slow Progression
- Evaluation of UKCS and Norwegian Continental Shelf
  - Most UKCS to UK
  - Norwegian gas ‘prioritised’ to Continent
  - Similar flows of UKCS and Norway in GG & SP
- Remaining shortfall of supplies to meet demand met by LNG and Continental imports
  - Bias towards LNG though high Continental imports considered as a sensitivity
- No new import or storage projects assumed but opportunities for both identified to encourage future development
- For network planning new projects are assumed to determine potential network reinforcements and investment

We create a single supply forecast for each demand scenario, to avoid multiple supply / demand scenarios

UKCS forecast based primarily on TBE data from Oil and Gas UK, this reflects the aggregate view of UKCS upstream parties. This forecast is prior to the governments announcement on tax changes.

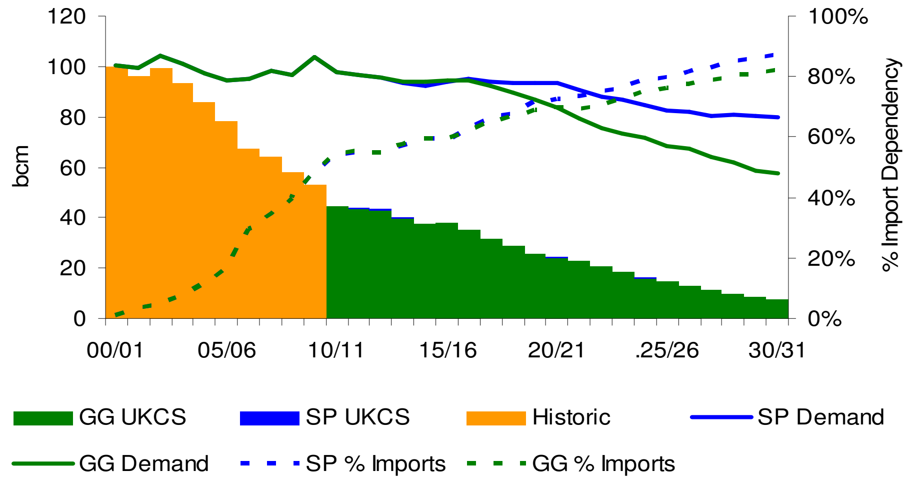
Norwegian forecast based on reported reserves and external forecasts for Troll and Ormen Lange.

With similar UKCS and Norwegian production profiles for the two demand scenarios, the resulting supply shortfall needs to be met by imports from LNG or the Continent.

Due to recent history, supply availability and a view that LNG pricing will be competitive, there is a bias in our forecasts towards LNG rather than the Continent.

To avoid ‘picking winners’ we do not assume any new import or storage projects, but identify the opportunities for both. For network planning we assume numerous new import and storage projects to determine potential network reinforcements and network investment.

UKCS Forecast



UKCS forecast based primarily on TBE data from Oil and Gas UK, this reflects the aggregate view of UKCS upstream parties. This forecast is prior to the governments announcement on tax changes.

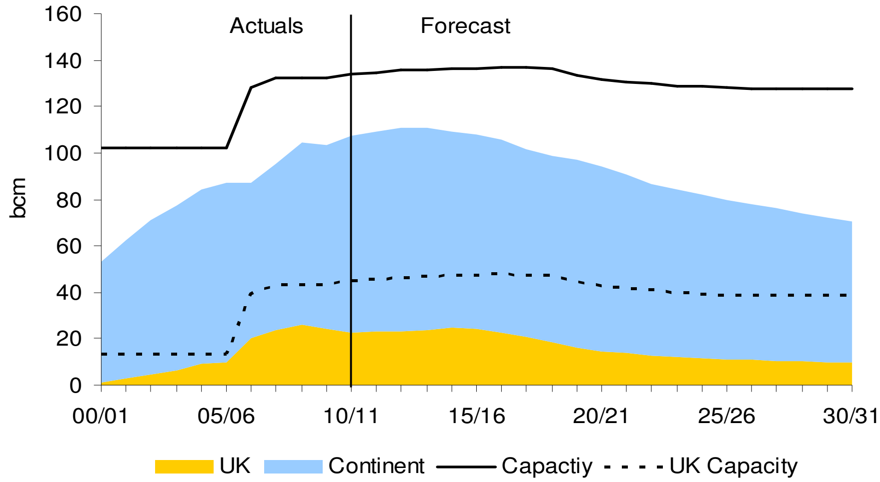
The rate of UKCS decline is forecast to slow over the next few years due to the development of some medium sized fields, West of Shetland (post 2014/15) and Sean blow down.

The big drop between 2009/10 and 2010/11 is due to some offshore issues particularly at St Fergus and the cessation of Rhum due to sanctions.

Though not shown, the supply forecasts include a contribution from unconventional gas, specifically coal bed methane (CBM) and biogas. For biogas 0.7 bcm (7.3 TWh) in 2020/21 and for CBM 0.6 bcm (6.7 TWh). Total unconventional production in 2030/31 is forecast at 2.6 bcm compared to 7.7 bcm for UKCS.

The forecasts for unconventional gas are subject to considerable uncertainty, shale gas is currently excluded from the forecasts, these therefore represent an upside.

Norwegian Forecast



The Norwegian capacity lines represent export pipelines to UK and the Continent only. The slight increase followed by decline in capacity reflects usage of UKCS pipelines.

The Norwegian forecast (excludes Norwegian LNG) is based on external forecasts for Troll and Ormen Lange and an assessment of remaining reserves for other fields / areas. Troll production is approximately 30 bcm/y throughout the forecast period whilst Ormen Lange declines from about 20 bcm/y. For other areas of production, published Norwegian reserve data is used with a scaling of 100% for areas in production and a 75% for less developed areas.

The production profile is based on a trend analysis that plateaus when 50% of total Norwegian reserves are produced, before commencing a decline. This is based on the UKCS experience, though the decline is less pronounced than experienced for the UK due to the Troll profile.

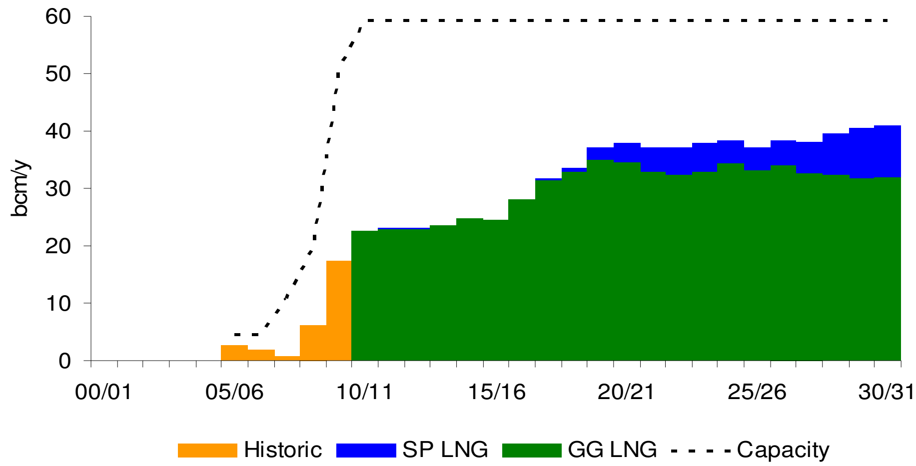
Flows to the Continent are prioritised based on historic flows and published contracts, with UKCS flows determined by difference.

As flows to UK reduce, there is increased opportunity for Norway to become a flexible (swing) provider to the UK, thus continuing to utilise existing import capacity of approximately 130 mcm/d. Opportunities for this are enhanced with greater Continental market access to storage and transmission.

Our latest Norwegian forecast is very similar to the FACTS forecast published in July 2011. Within a range of Norwegian production, this profile shows a general decline around 2020.

(FACTS – Norwegian Petroleum Directorate and Norwegian Ministry of Petroleum and Energy)

LNG

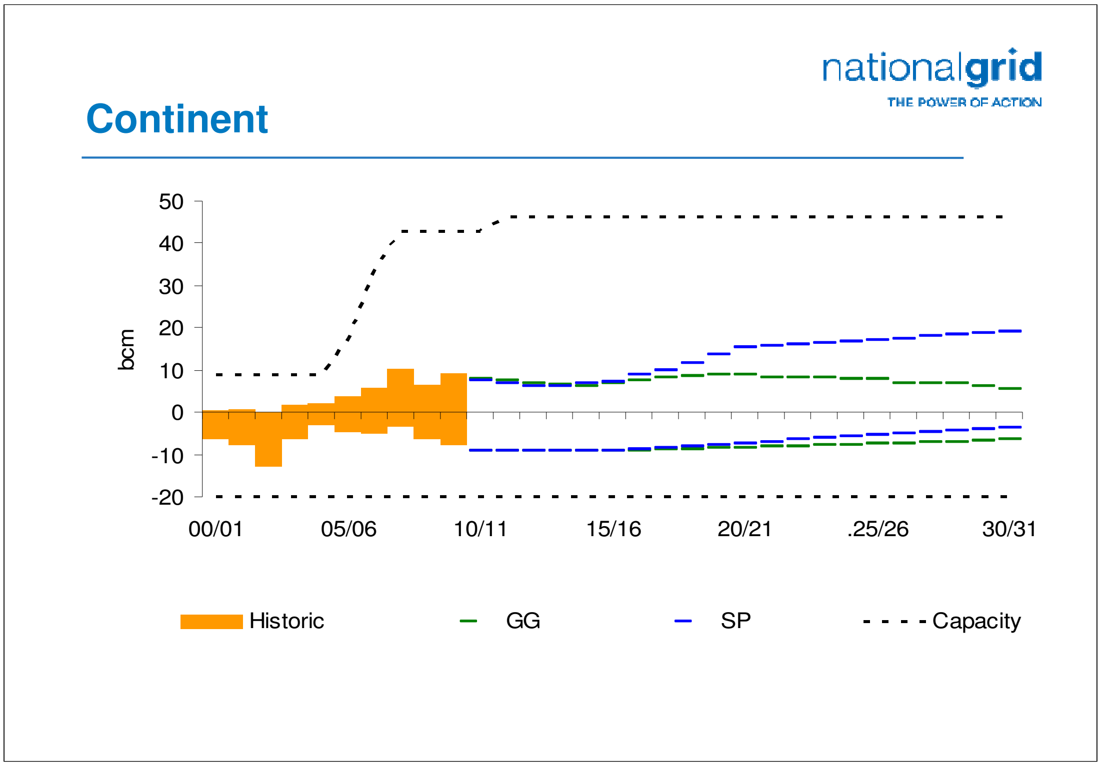


Our LNG forecast builds on the surge in LNG imports since 2008/9. Due to the global nature of LNG and the options to flow to alternative markets and the view that much of the LNG to the UK is not specifically contracted, these forecasts are subject to high levels of uncertainty.

Our LNG forecast is essentially the same for Gone Green and Slow Progression through to about 2017/18. The forecast includes a contribution from Teesside GasPort but no additional LNG expansion though high utilisation suggests additional LNG capacity could be needed.

The increase in LNG imports post 2015 is brought about through decline in UKCS and forecast commencement of decline from Norway.

LNG imports are higher in SP due to higher demand. LNG imports are shown to plateau at about 40 bcm or 70% of capacity. At these utilisation rates additional LNG import capacity may be needed, if not built some of the current LNG supply flexibility may be reduced.



Our Continental forecast includes imports through BBL and Interconnector (IUK) and exports through IUK. These imports / exports build on historic flows and on an annual basis only utilise some of the available capacity. For peak conditions most / all of the capacity is anticipated to be utilised. Due to supply options, like LNG these forecasts are subject to considerable uncertainty.

Our Continental forecast is essentially the same for Gone Green and Slow Progression through to about 2017/18.

The increase in Continental imports post 2015 in SP is brought about through a greater need for increased imports brought about by the decline in UKCS, forecast commencement of decline from Norway and high utilisation of existing LNG capacity. In GG post 2015, imports are lower due to lower UK demand and exports are higher due to UK supply availability brought about by LNG imports.

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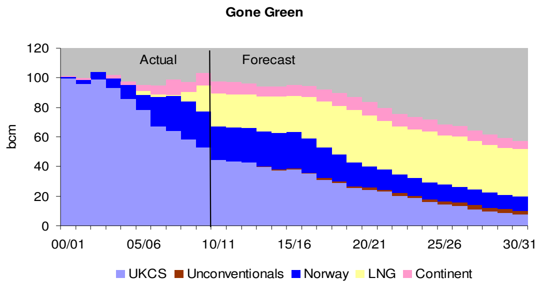
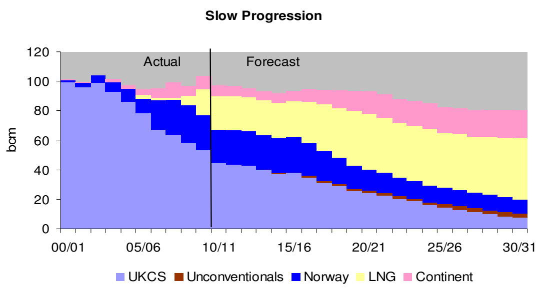
Annual Supply Forecasts





Key issues:

- Availability of LNG dictates Continental flows and influences gas price
- Norway to become a swing provider?
- LNG supply flexibility to reduce unless new import capacity is built?
- Declining UKCS results in increased supply (import) concentration – may lead to increased supply risk
- Managing demand variations through wind becomes increasingly important
- Storage will continue to provide a key balancing role

The charts show similar levels of UKCS and imports from Norway.

Compared to Gone Green higher demand in Slow Progression results in higher imports. These are met through higher LNG and Continental imports.

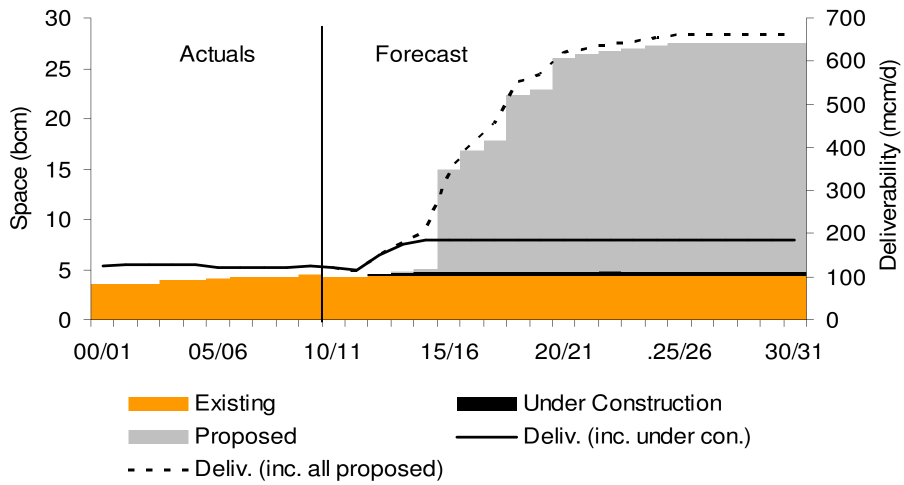
Imports in Gone Green are not materially higher than today as decline in UKCS is comparable to decline in demand. Due to need for CCGTs to cover for wind intermittency reduction in peak demand for GG is less pronounced.

As supplies from Norway decline, Norway could become a provider of peak gas to the UK as existing import capacity will remain. Liberalisation of Continental gas markets (notably access to storage and transmission) could enhance these opportunities.

Unless new LNG facilities are built, supply flexibility from LNG could be reduced due to the need to operate close to peak flows for much of the time.

Whilst the annual position looks manageable, the peak position is expected to become increasingly challenging due to the options for peak supply (more storage, LNG, Continental imports, possible Norwegian swing) and day to day and within day variations in demand caused through the intermittency effects of increased wind generation. All of this will require a network that can readily respond to increased supply and demand changes.

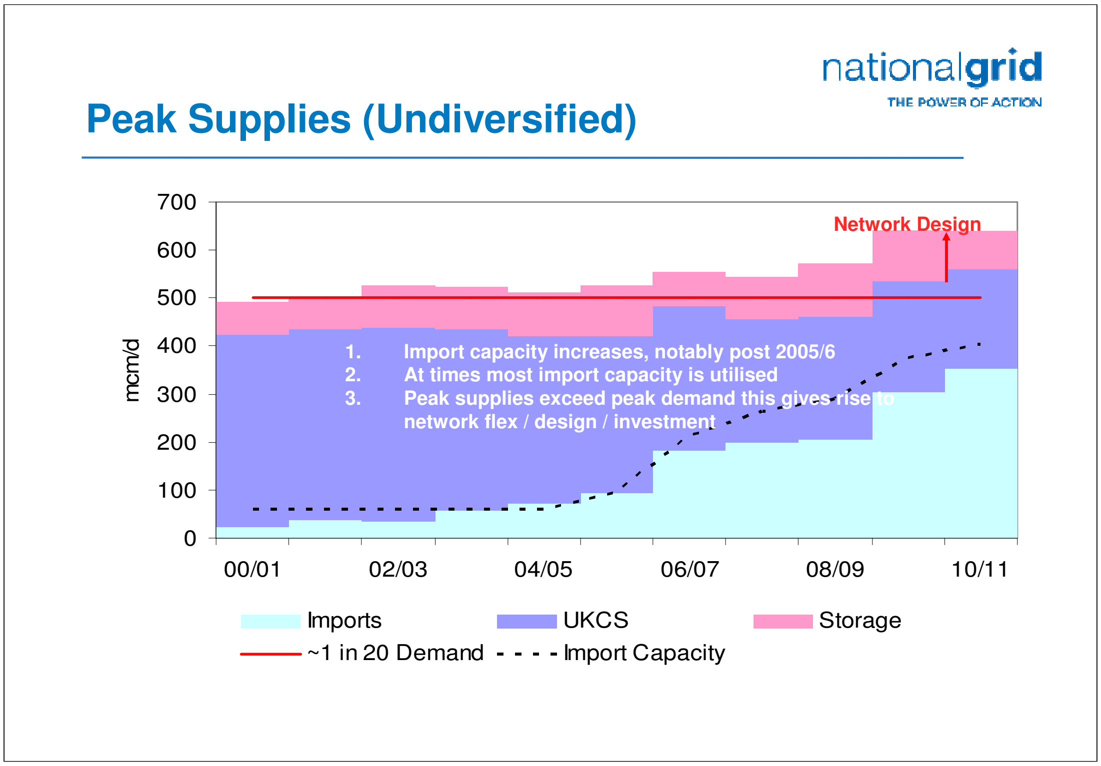
Storage



As in previous years the storage position is dominated by the potential for new storage projects that could be built over the next few years. Most of these are proposals rather than under construction. Those under construction tend to be facilities with high injection and withdrawal rates relative to their space. This enable them to operate relatively flexibly and cycle within winter.

Whilst the increase in storage space brought about by projects under construction is modest at about 0.4 bcm (less than a 10% increase in space), the resultant total storage deliverability could nearly double to approximately 200 mcm/d.

To avoid ‘picking winners’ we do not assume any new storage projects in either Slow Progression or Gone Green. Opportunities for new storage do however exist, for example to manage the increased demand variation brought about my more wind generation or to provide cover for supply losses. Due to increased supply concentration at entry terminals and the length of the supply chain, these are expected to increase and have a potential greater impact.



The chart shows the aggregation of all supplies by supply type / entry terminal since 2000. The chart highlights that increased import capacity has resulted in a significant increase in aggregated supply despite peak UKCS supplies declining from about 400 to 200 mcm/d.

In aggregate peak supplies now exceed 600 mcm/d, this far exceeds the estimate of peak demand of about 500 mcm/d. This highlights how the network needs to be designed, constructed and operated for numerous potential supply patterns rather than just peak day demand. With increasing levels of power generation from wind this need for increased supply flexibility is expected to increase. Higher storage deliverability will also significantly increase the needs of the network.

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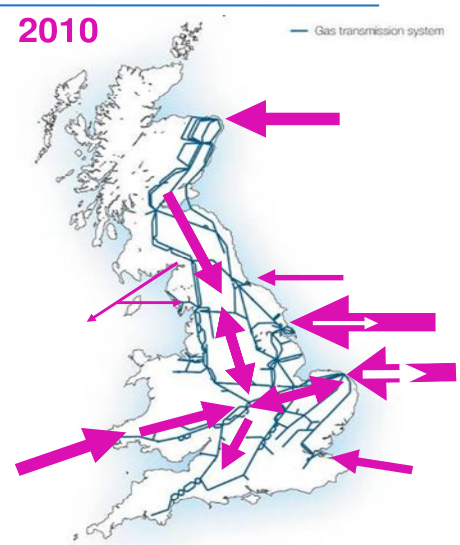
Changing Network Dynamics

- Network flows
- Network diversity
- Demand changes (notably wind)
- Supply variation and flexibility
  - Storage
  - LNG
  - IUK

- Network design / investment
- Operational challenges



This chart builds on the previous chart to identify other areas where network flows are changing and therefore the design, construction and operation of the NTS needs to be adapted for changing needs.

In 2000 the network flowed predominately from supplies in the north to demand in the south. Now the network is more diverse in terms of entry flows, however the permutations of such flows are considerable as are the consequences for supply losses and demand variations.

Conclusions

- Demand
  - Lower annuals (notably GG)
  - Peak, lower but comparable to today
  - Increased variation through wind
- Supplies
  - Lower UKCS, increased imports
  - Need for increased flexibility (storage, LNG, Continent, Norway?)
  - Opportunities for new imports / more storage
- Network design and operations
  - Managing greater uncertainty requires a more ‘flexible’ network

Notes

Notes

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