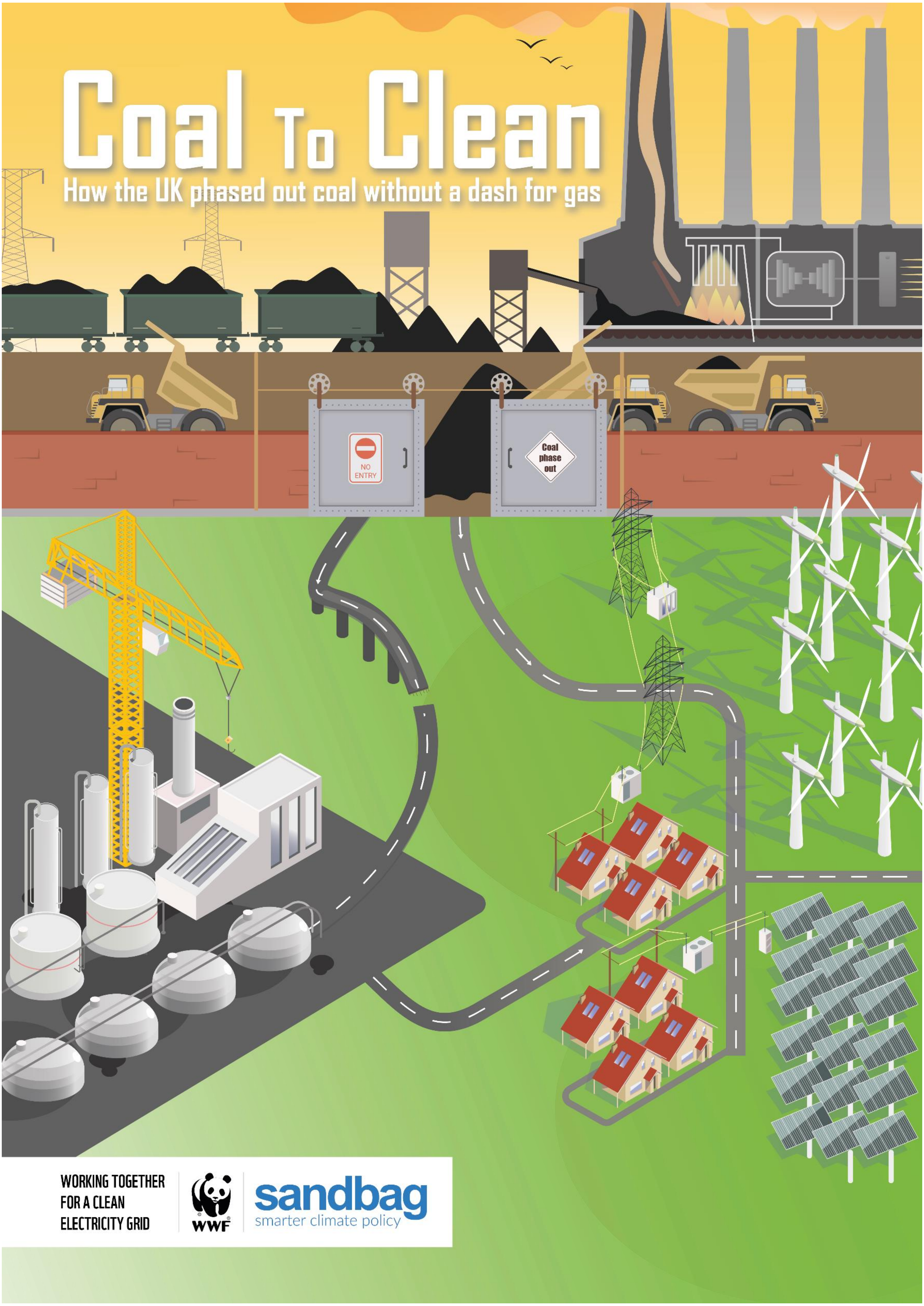
# Coal To Clean

## How the UK phased out coal without a dash for gas

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## How the UK phased out coal without a dash for gas

**01** **The UK is on track to phase-out coal by 2025 and keep the lights on without building <u>any</u> new large gas plants**

**02** **Renewables will completely replace coal generation by 2025**

**03** **The switch to a grid dominated by renewables means new capacity is only required to run infrequently – unsuitable for large gas**

**04** **Gas use in the electricity system has already peaked - but its rate of decline is less certain**

The UK coal phase-out was widely expected to involve a large, if temporary, switch to gas. This report takes a detailed look at the UK power sector, and reveals that the ‘gas bridge’ is unlikely to materialise: **the 2025 coal phase-out will be completed without building large gas plants.**

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When Amber Rudd, the Secretary of State, announced the UK coal phase-out back in 2015, she said: ***“in the next 10 years, it’s imperative that we get new gas-fired power stations built.”***

This laid the ground for a new dash for gas: in the latest capacity market in February 2018, 10 large gas plants with a capacity of 12GW applied for 15-year contracts, and a further five with a capacity of 10GW are readying themselves to apply in future auctions. This means almost half of all Europe’s prospective large gas plants are planned for the UK. However, ***so far***, not a single one has bid successfully for a capacity contract.

New large gas plants - which are designed to last 30+ years and are capable of operating 24/7 - are incompatible with the UK’s climate targets. According to the UK Government’s Clean Growth Strategy, the UK must lower gas generation from 40% of the electricity mix today, to 15% by 2032. It now looks likely the UK can leapfrog a ‘gas bridge’ to transition directly to clean power generation.

This report answers the following questions:

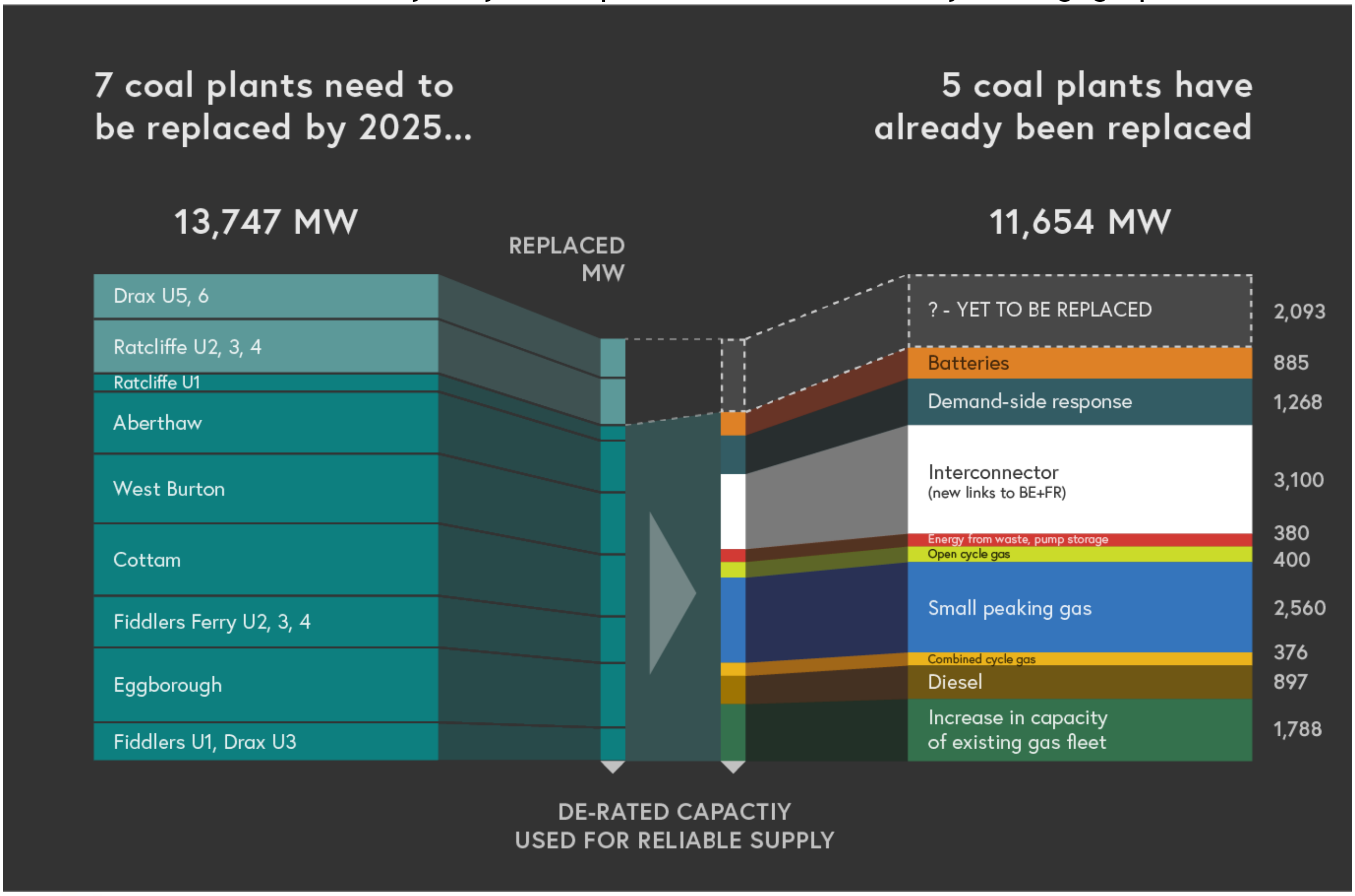
- Are enough renewables being built to replace coal, without increasing gas?
- Is it possible to avoid building any large gas plants, or are they needed to fill in the gaps of wind and solar after coal plants have retired?
- Should we be concerned if new large gas plants are built? What about small peaking gas plants?
- What policy steps should the Government take?

# Key findings

➤ **The UK is on track to phase-out coal by 2025 and keep the lights on without building <u>any</u> new large gas plants**

- One large gas plant (Carrington) went into operation in 2016, the first since 2012. Under current policy, it is likely to be the last large gas plant built in the UK.[1]
- By the end of 2016, there were seven coal plants left to replace, with a combined capacity of 14GW.
- Contracts to replace five of these have already been signed - half with interconnectors, battery and Demand Side Response (DSR) - the other half with fossil generation, mostly small peaking gas generators. This capacity comes online from 2018 to 2021.
- Our analysis shows the remaining two coal plants - just 2.8GW of capacity - are likely to be replaced in a similar manner, without the need for any new large gas plants.

**The Capacity Market auctions have already contracted most of the firm capacity required to replace coal - and the remainder is very likely to be replaced without a need for any new large gas plants**



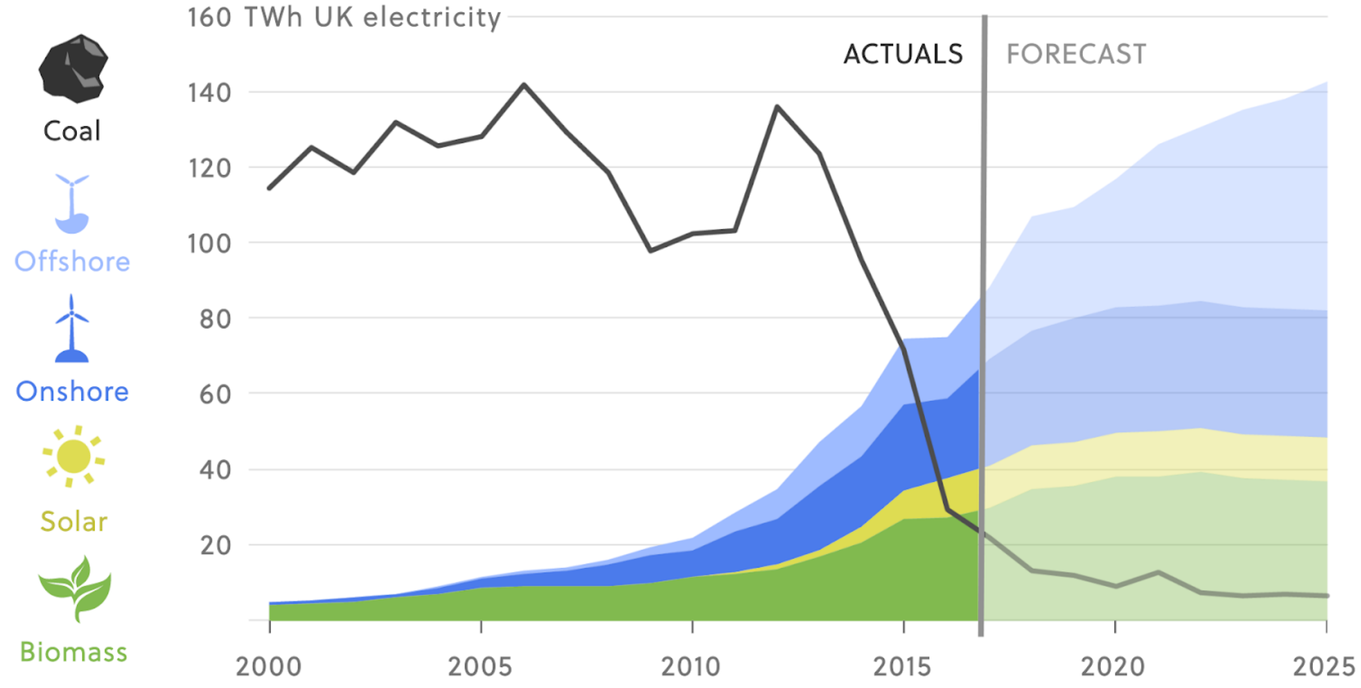

*Source: UK capacity market results to date*

[1] *We define large gas plants as those power stations with a total generating capacity of over ~450MW - the net power output for a typical F-Class turbine used in a CCGT.*

## ➤ Renewables will completely replace coal generation

- By 2025 electricity output from renewable sources will exceed the highest level of coal electricity generated in any year this century (which was 142 TWh in 2006).
- 95% of the required renewables growth to replace coal is already contracted or under construction, the Government has promised additional funding for the remainder. Offshore wind will provide most of the growth from 2017 to 2025.

**By 2025 electricity generated from renewables will surpass coal's peak this century**




*Source: 2000-2017 actuals from BEIS, 2017's figures are approximated using BEIS's quarterly* renewable energy trends. *Forecast from BEIS, CFD register, Ofgem FIT administrative data and Sandbag calculations.*

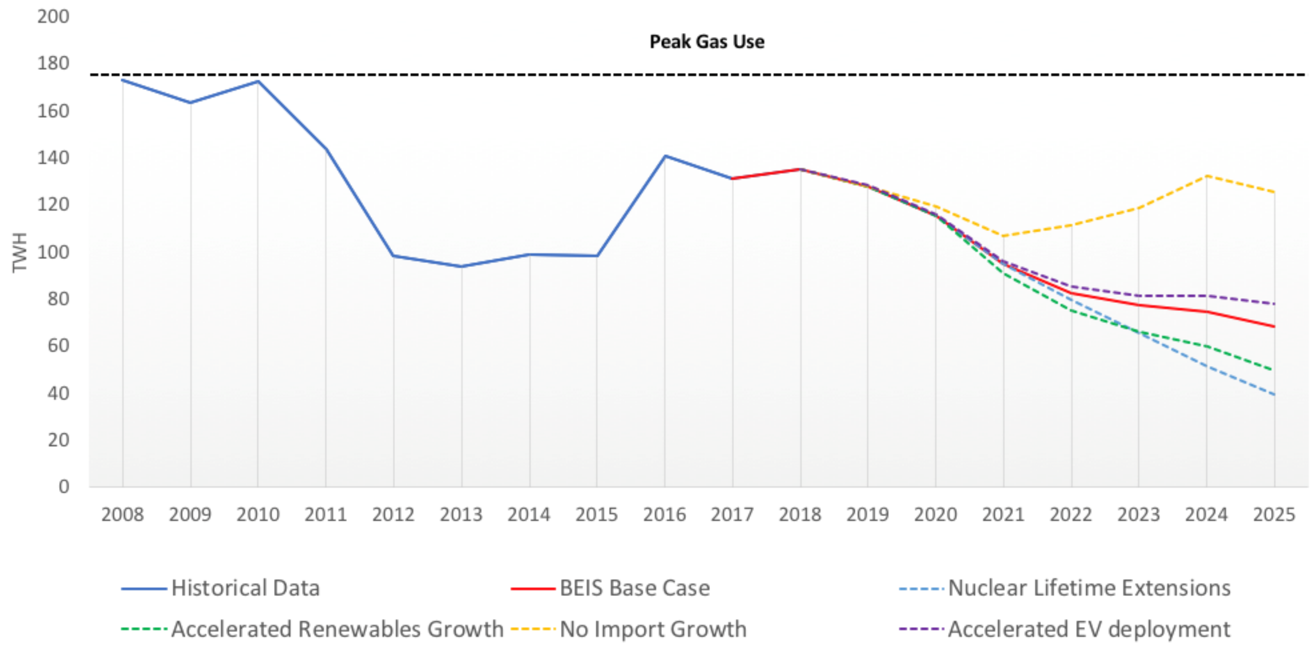
## ➤ The switch to a grid dominated by renewables means new capacity is only required to run infrequently - unsuitable for large gas plants

- Meeting capacity requirements with large gas plants would be unnecessarily costly for UK consumers and would lock the UK into higher gas use and carbon emissions.
- Already, the remaining coal plants do not operate very often (load factor averaged 19% in 2017).
- Our analysis shows the replacements for coal will need to operate even less (just 3% load factor in 2025 on conservative assumptions). As coal closes, the existing gas fleet will supplant some of coal's generation, and renewables will reduce the load further.

## ➤ Gas use in the electricity system has already peaked - but its rate of decline is less certain

- In 2017, gas use was already 24% below the peak set back in 2008. In the majority of plausible scenarios, gas use will be lower or significantly lower in 2025 than it was in 2017.
- The UK Government is relying on growing electricity imports to help decarbonise the electricity system: interconnectors are forecast to supply 22% of electricity by 2025. If this doesn't happen, existing gas would generate more, and carbon emissions would be ~ 70MT higher than BEIS's current projections by the end of 2025. Under such a scenario the UK would struggle to meet its legally binding carbon budgets.
- Even if electricity imports are lower than expected or demand is higher, the UK is still unlikely to need new large gas plants - small distributed technology will fill the gap more cheaply. This report shows that faster renewables growth and improved energy efficiency mitigates these policy risks.

**Gas use has already peaked - but the rate of future decline is less certain**




*Source: BEIS & Sandbag Calculations. Please see appendix 2 for more details on the scenarios.*

# Key recommendations

*The UK has so far successfully navigated the phase-out of coal, avoiding a gas bridge. However, meeting our carbon budgets in the next decade is not yet certain. Our recommendations for the Government are:*

1. **Unleash the potential of solar and onshore wind now.**
    a. Currently the lion's share of the UK's renewables growth to 2025 will come from offshore wind. A fast and cost-effective way to keep reducing gas emissions throughout the early 2020's is a subsidy-free CFD auction for onshore wind and solar. Both technologies have short construction lead times and significant existing planning consent. Onshore wind is demonstrably cheaper than UK electricity wholesale prices, and with the UK's first subsidy-free PV farm already commissioned, solar should be competitive too.

2. **Do not bring forward policy measures to support new build large gas.**
    a. The lights will stay on after coal has been phased out - without new build large gas. On March 20th, Claire Perry MP announced a review of the Capacity Market - this review <u>should not</u> promote new build large gas.

3. **Prevent excess emissions from small peaking gas.**
    a. Policy is needed to address the emissions from small peaking gas as poor market design may be artificially inflating running hours. The $450gCO_2/kWh$ instantaneous limit proposed in the coal phase-out legislation should be extended to all new build generation with a thermal capacity of over 1MW. This will ensure small peaking gas is only used when absolutely necessary to support the grid.

4. **Increase innovation funding for long term electricity storage technologies.**
    a. Longer-term electricity storage will be required to fill in for seasonal and multi-day lulls in renewables output if we are to phase-out gas from our electricity mix in the long term. While we welcome recent Government funding commitments in energy storage, we recommend the Government sets up an innovation fund to tackle long-term electricity storage specifically.

5. **Mitigate the risk of a slower fall in gas use and begin planning now for a gas phase-out.**
    a. Policy is needed immediately to mitigate the risk of a slower decline in gas use caused by: increasing demand; delayed or cancelled new-build nuclear projects; or a reduced volume of electricity imports. Longer term, the government should look at the role of seasonal energy storage and carbon capture and storage technology in reducing gas emissions to zero.

***About the data:*** *Sandbag's new hourly generation and offshore wind models allow for an independent assessment of the Government's plans to achieve the 2025 coal phase-out.*
*We put forward new scenarios which, given the operating hours of each section of the existing gas fleet, examine the need for new-build gas generation. With the exception of the historical offshore wind speed data used to drive our wind generation model, all the data used in this report is publicly available. The Department for Business, Energy and Industrial Strategy (BEIS) is our primary source. The CFD register & Ofgem's FIT administrative data provided further detail on the projected deployment of large and small scale renewables respectively. Historical half hourly power generation data is sourced from National Grid and Entsoe. Please refer to Appendix 2 for more detail on the models.*

# Contents

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**Authors** Charles Moore, Phil MacDonald, Dave Jones

**Graphics** Wilf Lytton

# Chapter 1 - The story so far

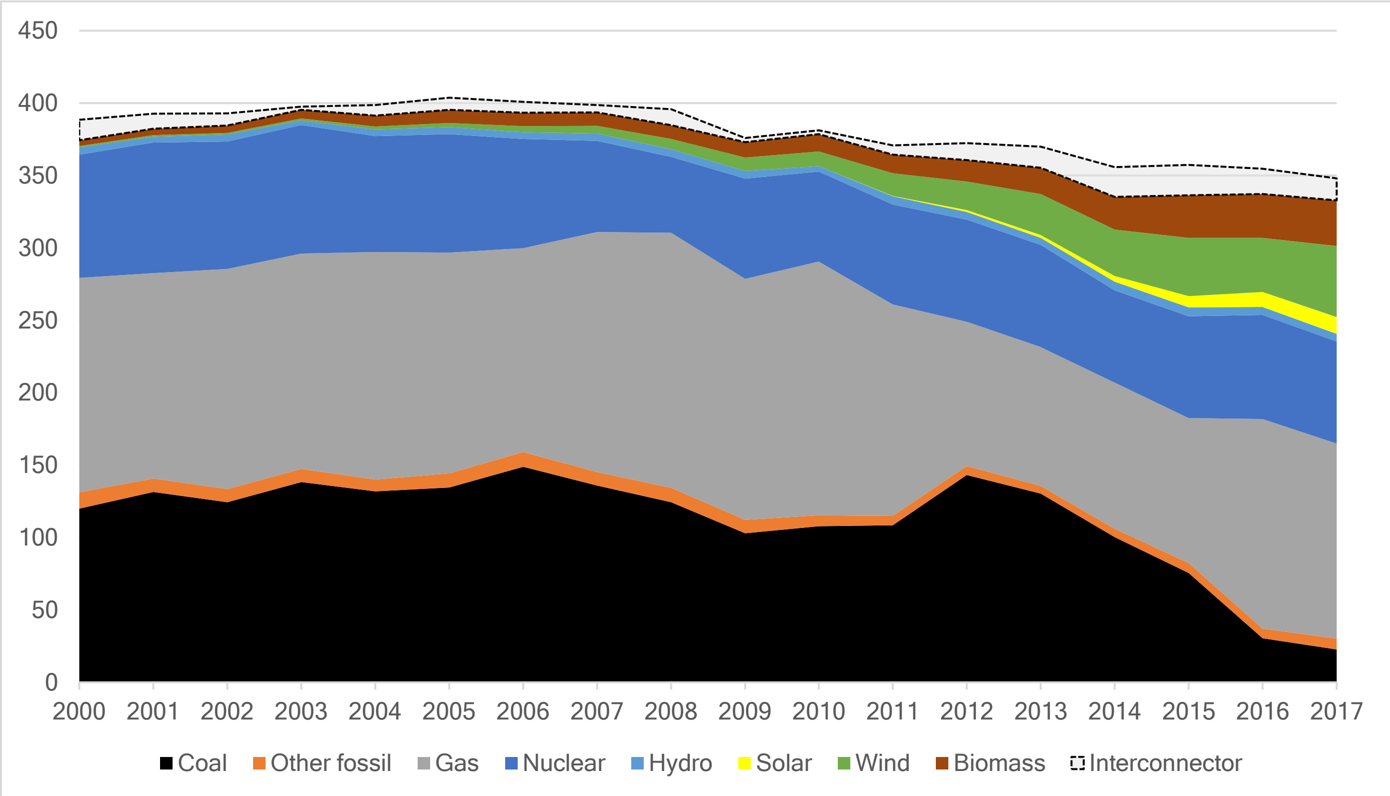
Dramatic changes have been taking place in the UK electricity market. In just five years, from the start of 2012 to the end of 2016:

- Half of the UK's coal power plants closed - an incredible 12 plants, representing 15GW. This has left seven coal plants operational, with a combined capacity of 14GW.
- 23GW of renewables was commissioned - 9.6GW wind, 10.9GW solar and 2.6GW biofuel.
- The coal phase-out and the Capacity Market has got developers of gas power plants salivating. 15 large gas projects with a capacity of 22GW are vying to be built. However, none of these have yet been given capacity contracts - and current policy looks unlikely to support them.

The underlying market has also changed significantly. In 2012, any renewable project required large subsidies to get off the ground. Now, no new *fossil project* can be built without significant Capacity Market subsidies, while onshore and offshore wind prices creep within spitting distance of wholesale prices, and the first subsidy-free solar project has already been built.[2]

*This chapter explains these recent changes - and the groundwork over the preceding years that led to this happening.*

**Figure 1. UK electricity generation mix 2000-2017 (TWh)**



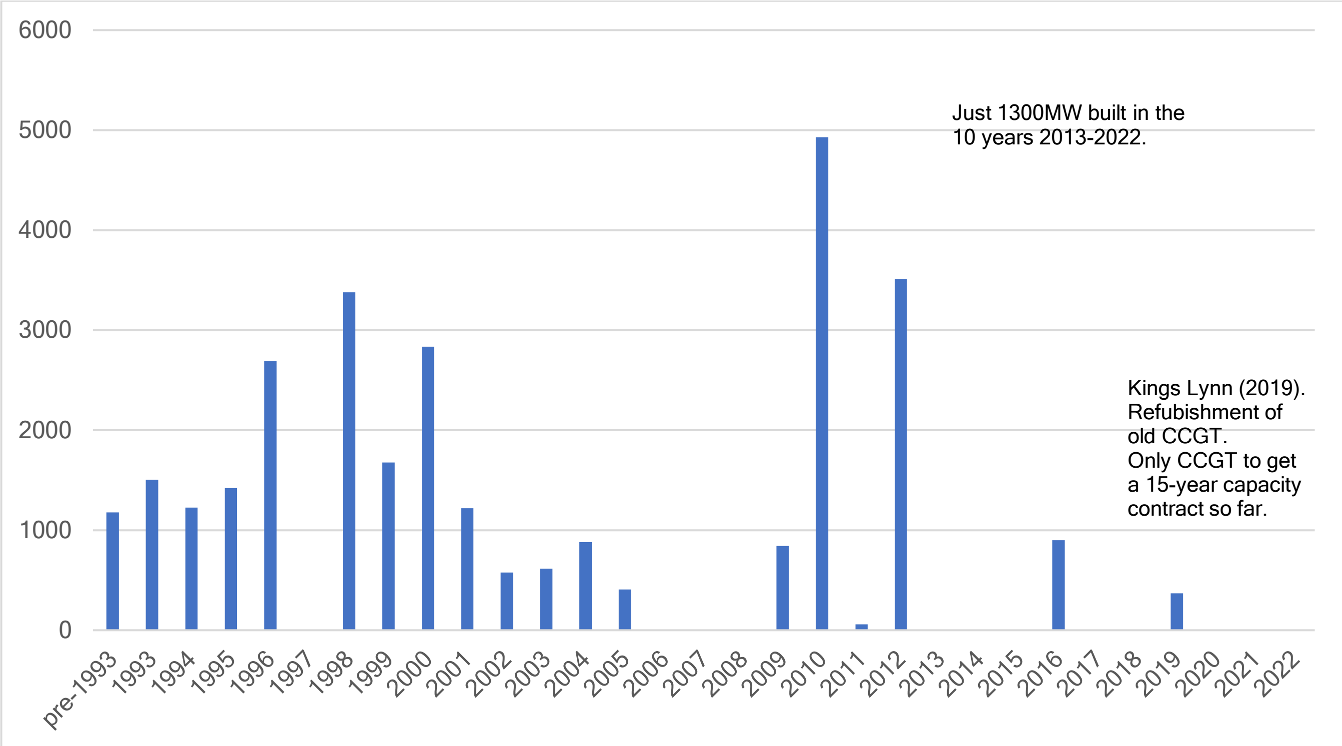

### The Real Threat of Gas

In the 1990s, the first "dash for gas" took place. Taking advantage of cheap North Sea gas, the UK made major investments in gas plants, going from less than 2% of generation in 1990 to 40% by 2000. A second wave took place more recently, with 9GW coming online from 2009 to 2012. After a four year

[2] [Subsidy free solar comes to the UK]() *(26th Sept 2017) Claire Perry, BEIS*

gap, a large gas plant, Carrington, came online in 2016. A small gas plant refurbishment at Kings Lynn in planned for 2019.

**Figure 2. History of UK large gas build (CCGT)**




*Source: DUKES*

Following a cross-party pledge in early 2015 to phase-out coal, the Conservative Government announced the UK coal phase-out directly before the Paris COP in 2015. In the coal phase-out announcement itself, the Secretary of State said:

> ***"In the next 10 years, it's imperative that we get new gas-fired power stations built. One of the greatest and most cost-effective contributions we can make to emission reductions in electricity is by replacing coal-fired power stations with gas."***[3]

Was this the start of a new "dash for gas"?

The Capacity Market was set up as part of the Electricity Market Reform programme in the 2013 Energy Act to ensure reliable sources of capacity to deliver energy when needed. This provides a route for new large gas plants to be built and receive 15-year contracts for generation, providing they can bid in at a competitive price.

In addition, by knocking out coal the high carbon price in the UK also created a favourable incentive for new large gas plant. The Carbon Price Support is now fixed at its current value at least "until unabated coal is no longer used".[4]

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[3] *A new direction for energy policy (Nov 2015) Amber Rudd, DECC*
[4] *The Carbon Price Support was fixed at £18/t$CO_2$ in the Autumn Budget (Nov 2017)*

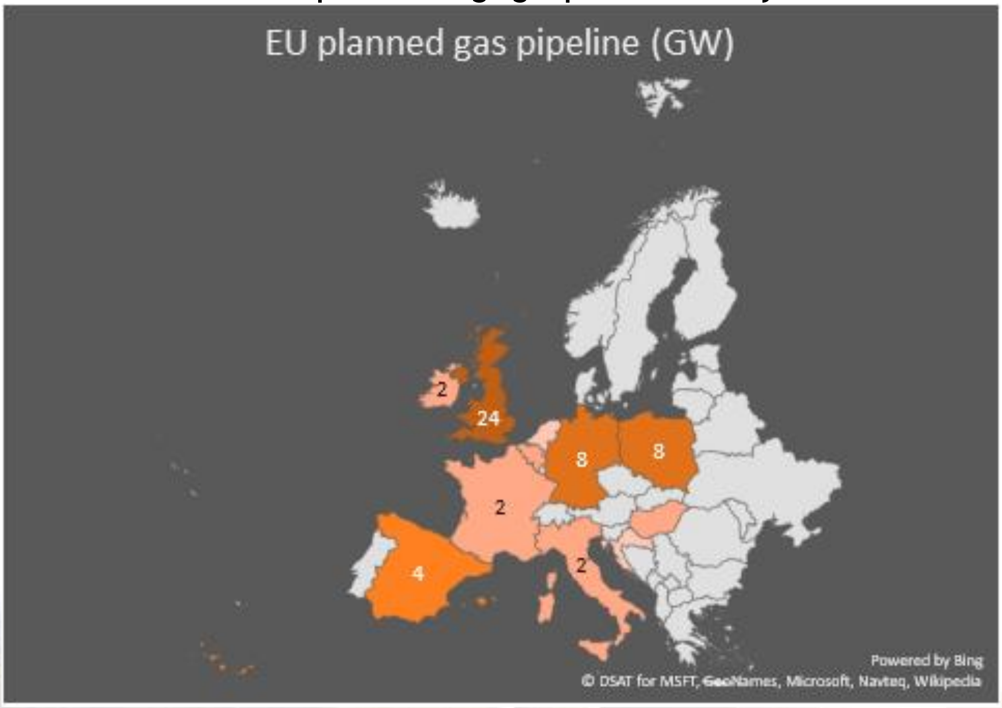
As excitement about the potential for support under the Capacity Market grew, a large number of new gas plants were proposed. In the latest Capacity Market auction in February 2018, ten large gas plants with a capacity of 12GW applied for 15-year contracts, and a further five large gas plants with a capacity of 10GW are readying themselves to apply for 15-year contracts in future auctions.

**Figure 3. There are a large number of potential new UK gas projects - but the nature of the Capacity Market means it is unlikely any will be built**

| Project Name | Developer | Capacity (MW) | Status |
|---|---|---|---|
| Trafford Power CCGT | Carlton Power | 1800 | Bid In Capacity Market |
| Damhead Creek 2 CCGT | Scottish Power | 1730 | Bid In Capacity Market |
| Knottingley Unit 1+2 | ESB | 1658 | Bid In Capacity Market |
| Thorpe Marsh CCGT | Carlton Power | 1600 | Bid In Capacity Market |
| Willington C CCGT | Calon Energy Limited | 1530 | Bid In Capacity Market |
| Gateway Energy Centre | InterGen | 1217 | Bid In Capacity Market |
| Keadby 2 | SSE Generation Limited | 852 | Bid In Capacity Market |
| King's Lynn B | EP UK Investments Ltd | 844 | Bid In Capacity Market |
| Spalding Energy Expansion | InterGen | 530 | Bid In Capacity Market |
| C.GEN Killingholme | C.GEN SA | 522 | Bid In Capacity Market |
| Drax | Drax Power Ltd | 3600 | IN PLANNING |
| Tilbury | RWE Generation | 2500 | IN PLANNING |
| Eggborough | Eggborough Power Limited | 2500 | IN PLANNING |
| Abernedd | SSE Generation Limited | 870 | IN PLANNING |
| Drakelow | Powersite DL Ltd | 390 | IN PLANNING |
| Seabank 3 | SSE Generation Limited | 1440 | PAUSED |
| Sutton Bridge | EDF Energy | 1400 | UNCLEAR |

Figure 4 shows that the UK is the main location for new gas generation in Europe. According to Platt's Power Station Tracker, **almost half** the new gas power plants planned in Europe are in the UK.

**Figure 4. The UK has more planned large gas plants than anywhere else in the EU**




*Source: Platt's Power Station Tracker 2017; CCGT plants "applied" or "approved" to be built; UK data from Sandbag*

## Coal Closures

Coal's role in the electricity mix is already in terminal decline. As recently as 2012 coal produced nearly 40% of the UK's electricity, but by 2017 that had already fallen to 7%. Coal capacity has fallen from 30GW to just 14GW, with 12 plants closing since 2012.

This is doubly as impressive since a further 8GW of gas and oil plant closed in these five years, totalling 23GW of fossil fuel-based plant closures. Additionally, the last 1.5GW of the UK's first-generation nuclear plants also closed.

Figure 5 shows ***why*** these 12 coal plants closed. There are broadly three reasons. First, 8GW out of the 15GW opted out of the EU Large Combustion Plant Directive back in 2007, which meant that these plants needed to close by December 2015. Second, the UK Government awarded biomass contracts to convert 2.4GW of coal plants to run on biomass, which meant three units at Drax and one unit at Lynemouth no longer burn coal. Third, the remaining oldest and dirtiest coal plants became uneconomic - partly because of the UK's carbon tax, and partly because they could not justify investment to comply with tighter future EU emissions limits.

**Figure 5. Coal closures from 2012-2016**

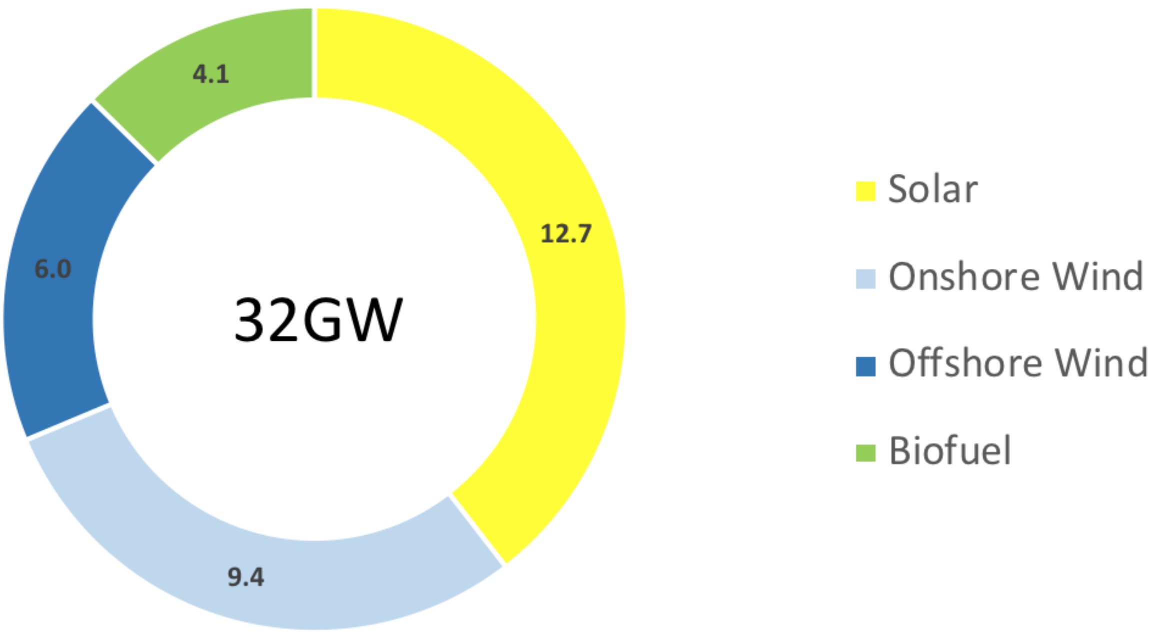
| Plant Name | MW | Opened | Retirement | Reason |
|---|---|---|---|---|
| Ferrybridge C | 980 | 1966 | 2014 | Opt-out LCPD |
| Kingsnorth | 1,940 | 1970 | 2012 | Opt-out LCPD |
| Ironbridge | 970 | 1970 | 2013 | Opt-out LCPD |
| Tilbury B | 1,020 | 1968 | 2013 | Opt-out LCPD |
| Didcot A | 1,925 | 1972 | 2013 | Opt-out LCPD |
| Cockenzie | 1,152 | 1967 | 2013 | Opt-out LCPD |
| Lynemouth | 420 | 1995 | 2015 | Biomass conversion |
| Drax | 1,935 | 1974 | 2013-5 | Biomass conversion |
| Uskmouth | 393 | 2000 | 2014 | Uneconomic / end of life |
| Ferrybridge C | 986 | 1966 | 2016 | Uneconomic / end of life |
| Rugeley | 1,006 | 1972 | 2016 | Uneconomic / end of life |
| Longannet | 2,304 | 1970 | 2016 | Uneconomic / end of life |

*Source: Dukes, 2012- 2016; "Reason" categorised by Sandbag author*

How was so much plant able close without the lights going out? The simple answer is that overcapacity had plagued the UK market for a long time, and most of the closures happened simply as a result of this excess. The oversupply was mainly from a combination of falling demand, new-build large gas plant, and new renewable capacity.

In addition, since 2000, UK electricity demand has fallen by 10% - the only EU country other than Sweden that has seen electricity demand fall over this period. The reasons for this are complex and not fully understood. More explanation can be found in Sandbag's report: *The European Power Sector in 2017*.

**Figure 6. 32 GW of renewable capacity has been installed since the start of this decade**




*Source: BEIS renewable energy trends, data up to the end of Q3 2017*

### The Growth of Renewables

UK Government policies to support renewables generation have had a substantial impact on the UK's generation mix. Between 2012 and 2017, renewables have increased from 11% of the electricity supply to 28%. Support for renewables has seen prices rapidly fall. The cost of solar and wind now close to the wholesale price of electricity, thanks to policies including Feed In Tariffs (FITs), the Renewables Obligation (RO), Investment Contracts and Contracts for Difference (CFDs). Biomass however continues to demand large subsidies, and there appears to be no current political appetite to support further projects.

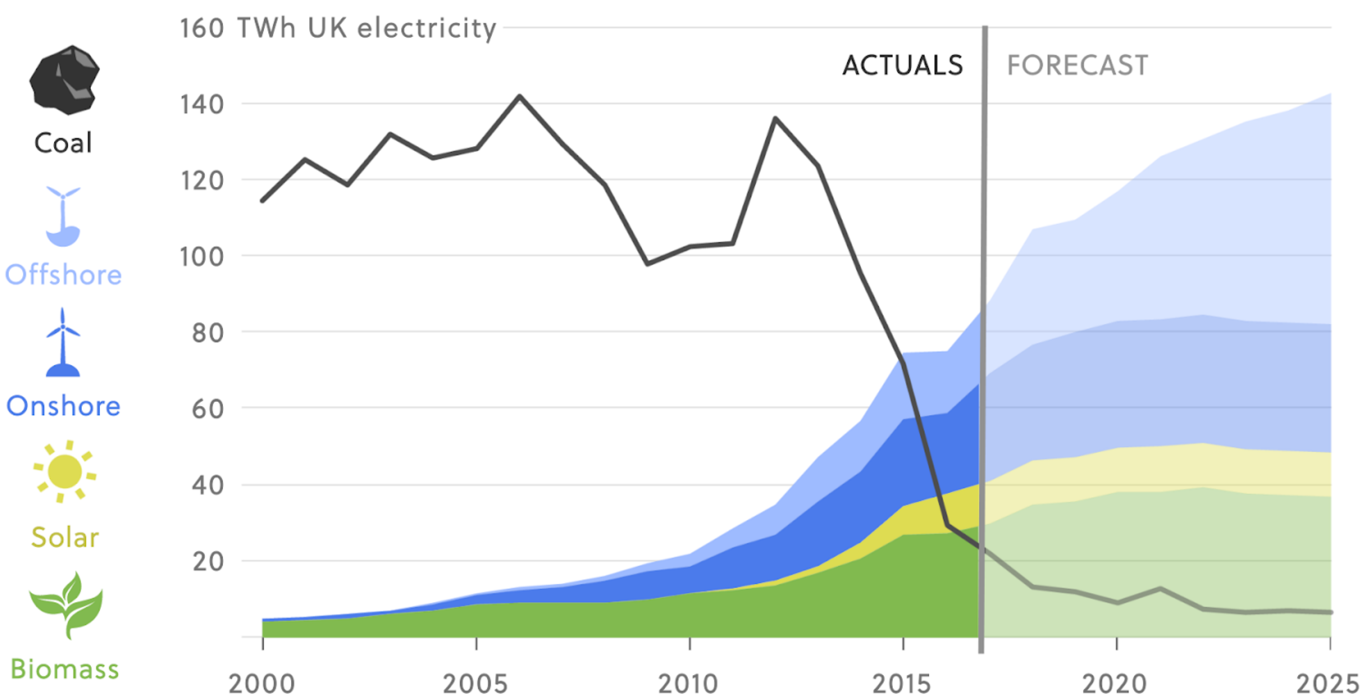
# Chapter 2 – The electricity mix in 2025

There are three key themes driving changes in the UK electricity mix to 2025: the rise of renewables, the demise of coal, and the growth of interconnection. Each of these will impact gas demand. This will be explored in detail later in the chapter.

**The Rise of Renewables Continues**
By 2020 renewables are forecast to be the single largest source of electricity generation in the UK.

By 2025 renewables will account for over 40% of the UK's electricity demand.[5] Electricity output from renewable sources in 2025 will exceed the highest level of coal generation observed this century (142 TWh in 2006).

**Figure 7. By 2025 electricity generated from renewables will surpass coal's peak this century**




*Source: 2000-2017 actuals from BEIS, 2017 figures are approximated using BEIS's quarterly* Renewable Energy Trends. *Forecast from BEIS, CFD register, Ofgem FIT administrative data and Sandbag calculations.*

Using data from BEIS, the CFD register, and the Ofgem FIT administrative data (with Sandbag's own calculations when these sources are known to be out of date), we have split BEIS's total renewable generation forecast by type.

From 2018 the majority of growth will be driven by offshore wind, output from which is forecast to ~ triple vs. 2017.

[5] *Updated Energy & Emissions Projections (Jan 2018) BEIS*

The growth in electricity generation from biomass is slowing. By the end of 2018, coal-biomass co-firing will be negligible, and the least efficient power plants burning biomass (Ironbridge and Tilbury) have already closed. Electricity generation from biomass will increase from 35TWh in 2018 to 37TWh in 2025 mostly as result of the commissioning of a new biomass combined heat and power plant at Teesside.

Onshore wind and solar PV are forecast to provide very little growth to 2025 due to the reduction in Government support. Onshore wind output is expected to grow only 10% from 2018 to 2025 due to the additions of the last projects under the RO and earlier CFDs; solar is projected to grow just 2%.

**How confident are we that renewables will deliver?**

> *95% of the required renewables growth to replace coal is already contracted or under construction, and the Government has committed additional funding for the remainder.*

The Government's conservative forecast expects annual renewables output will grow by 48TWh from 2017 to 2025, and most of this has already been contracted to be built. To date, the Government has conducted two CFD auctions to support the deployment of renewables. In addition, the Government has granted Investment Contracts (early CFDs) to eight renewables projects, through a process known as Final Investment Decision Enabling for Renewables.[6]

Analysis[7] from the LSE Grantham Research Institute (independently verified by Sandbag) calculates that projects yet to be delivered under these schemes will result in a 37TWh increase in annual renewables output by 2025. These figures do not include the output from ROC accredited wind farms due for completion throughout 2017 and 2018. We estimate that the offshore sites will add at least a further 4TWh,[8] while the onshore installations will contribute an additional 4.5TWh.[9]

This leaves just 2.5TWh of additional renewables generation to find to fully replace coal - approximately the output from 0.6GW of offshore wind capacity.

In the Clean Growth Strategy, BEIS promised a further £557m of annual funding to support contracts for low carbon generation. The first auction to allocate these funds will take place in 2019. In 2018's record breaking auction, 3.2GW of offshore wind (and a small volume of other renewable generation) was contracted for an estimated annual commitment of £176m.[10] Therefore, even if prices do not continue to fall, there is more than enough funding available to meet the Government's renewables forecasts.

*In fact, it is more likely that these renewable forecasts will be exceeded.*

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[6] *Final Investment Decision Enabling for Renewables (April 2014) BEIS*
[7] *New projections (January 2018) Bob Ward, LSE Grantham Research Institute on Climate Change and the Environment*
[8] *The offshore wind farms in question are Race Bank, Galloper & Rampion. At a load factor of 47.3% (HMRC assumption) output will be 5.5TWh. Race bank achieved full power in early February 2018 and operator Orsted stated that it had delivered 1TWh during commissioning. Rampion and Galloper reached first power in late 2017.*
[9] *Calculated cross referencing RenewableUK total 2017 installed onshore wind capacity figure (2.6GW) with BEIS's quarterly Energy Trends: Renewables figures to estimate the 2017 output of this new capacity vs. expected output of the total capacity in a normal year (7TWh using 33% load factor).*
[10] *Contracts for Difference Second Allocation Round Results (September 2017) BEIS*

## Coal's Demise

The UK Government has committed to phasing out all unabated coal power generation by October 2025. However, market pressures are likely to force most of the UK's coal fleet to close before then - the Government expects just 1.5GW to remain online in 2025, down from 14GW today.[11] With just two plants left to replace, it would be possible for the coal phase-out to be brought forward to 2023.[12] Electricity generation from gas will generally remain cheaper than coal thanks to the UK's Carbon Price Support. Remaining coal is likely to continue to generate only for short periods during winter. This support to the grid was useful for periods such as January 2017, when wind generation was below average, and France had little spare electricity to export.

To date, of the seven remaining coal plants, Eggborough is the only one with a firm retirement date, but we expect further announcements imminently.

## An Explosion in Interconnection

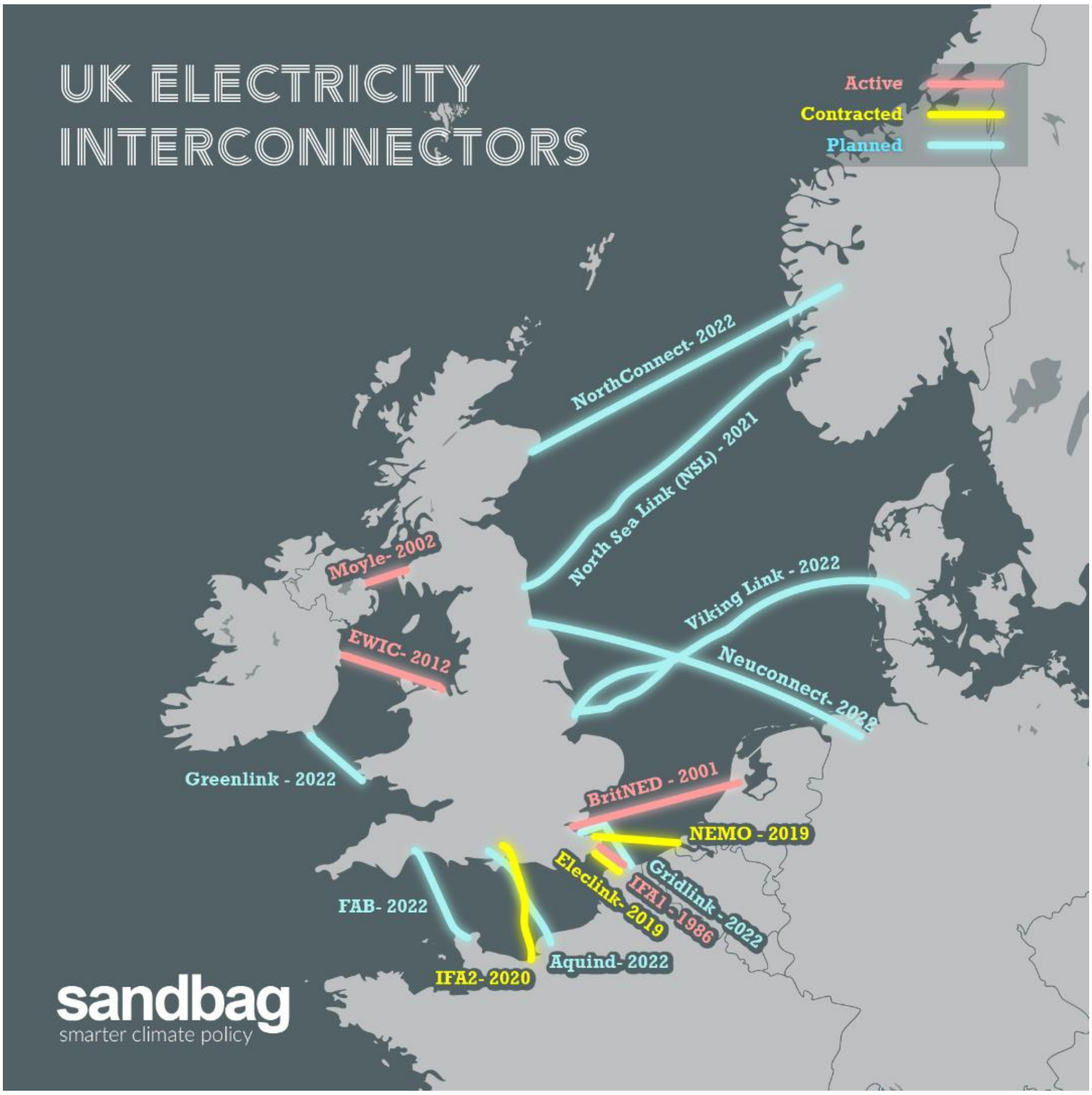
An interconnector is a cable that allows electricity to flow between one country's power grid and another's. The UK currently has 4.3GW of interconnector capacity and is a net importer of electricity. 6% of demand is currently met by power generated in other countries.

The UK's tax on carbon emissions is higher than the other Member States and this, alongside the UK's high reliance on gas, results in generally higher wholesale electricity prices. Interconnectors take advantage of this price differential to generate revenues, but their owners are exposed to the risk that regulatory or technological changes in the markets they link may result in lower revenues than expected. However, since May 2014, Ofgem's cap and floor regime means new interconnectors have been able to guarantee their future revenue - a profitable and low-risk route for developers. Subsequently there are a large number of new interconnectors currently planned.

Sandbag's analysis shows that there are 11GW of interconnectors at various stages of development accepted into the cap and floor regime. A further 1GW project not in the regime (Eurotunnel's Eleclink) is already under construction. The Government expects that interconnection capacity with the continent will quadruple between now and 2025, and modelling assumes they will generally be used to import electricity. **BEIS forecasts that imports will provide 22% of the UK's electricity needs by 2025, up from 6% in 2017**.

[11] *Impact Assessment: The Future of Coal Generation in Great Britain (Jan 2018) BEIS*
[12] *Phasing-out Coal by 2023 (Feb 2017) Sandbag*

**Figure 8. Active, contracted and planned UK interconnectors**



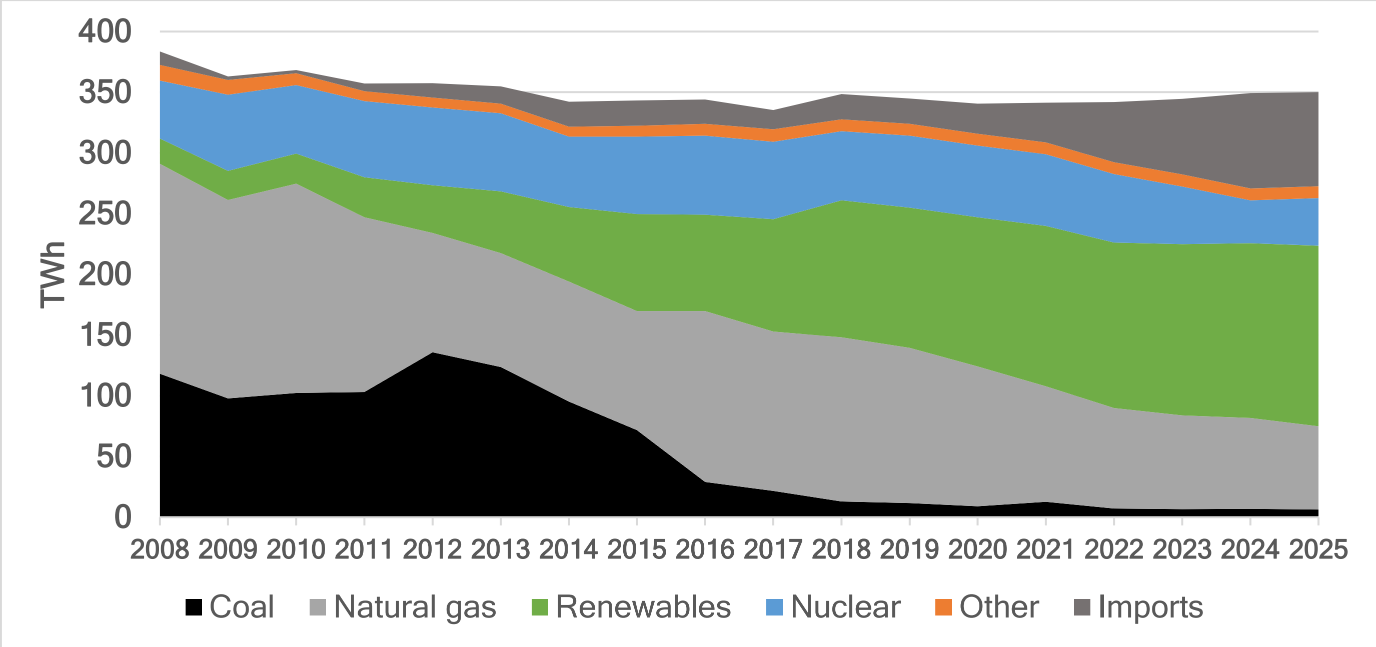

*Source: Ofgem*

# 2.1 - What does this mean for Gas use?

Gas generation has peaked, and its role will change significantly over the next decade.

In 2017, gas use was already 24% below the peak set back in 2008 (at which point gas was providing 45% of UK electricity generation). BEIS projections show gas use continuing to fall to 2025, almost halving again from 2017 use. We have also modelled other plausible scenarios for the power sector, which we discuss later in the chapter.

**Figure 9. Historic & Projected UK Electricity Generation by Fuel Type, 2008-2025 (TWh)**




*Source: 2008-2016 actuals from BEIS, 2017 figures are approximated using BEIS's quarterly figures & National Grid data. 2018 forecast from BEIS, corrected to make historical and forecast data consistent.*

In recent years gas power plants have been the cornerstone of the UK's electricity grid. However, with renewables and imports from the continent expected to grow, gas will be progressively squeezed out and relegated to a balancing role - only running to fill in the gaps when other sources of supply are unavailable. Total running hours will likely decline.

Gas' balancing role makes accurate forecasting more difficult - generation will depend on how other electricity sources perform, especially supply via the interconnectors. That said, the target is clear:

> ***To meet the UK's climate targets, the Government's Clean Growth Strategy envisages gas supplying just 15% of the UK's electricity needs by 2032, down from 40% today.***[13]

If we are reliant on such low gas generation levels to meet our carbon budgets, we need concrete policy to ensure this.

The rate of decline will be steepest in the early 2020s with gas' share of the electricity mix projected to fall to just over 20% by 2025.

This report focuses on the changing electricity mix before 2025. However, BEIS projections out to 2035 show a 'long tail' to this low gas demand, with some infrequently-used gas capacity being required for the foreseeable future.

To fully decarbonise the electricity system and phase out unabated gas after 2025 there would need to be either: a switch from gas into long-term seasonal energy storage; or a switch into burning hydrogen rather than methane; or temporary deployment of carbon capture and storage (CCS) technology with gas plants built in suitable locations - and potentially a mix of all three. Use of hydrogen opens up possibilities for further reductions in gas if it can be extended to the heat network. However none of

[13] *Pg. 141 Clean Growth Strategy (Oct 2017) UK Government*

these options are yet available for deployment at scale. The Government and industry have a clear role to play in driving the investment and innovation needed to make them viable options.

If CCS is not deployed at scale, the Committee on Climate Change states that to meet Climate Change Act obligations "*gas would cease to be used for electricity generation by the mid-2030s*".[14]

The Government needs to plan now for how it can make unabated gas phase-out a reality.

## 2.2 - What are the key uncertainties in the Government's forecast?

The Government's forecast sets the UK on a path to providing just 20% of its electricity needs from fossil fuels by 2025, but as with any forecast, real life may prove to be quite different. Below we outline what we consider to be the key risks and uncertainties in the forecast and their potential impact on the grid and the UK's carbon emissions in 2025.

**Interconnectors**
The Government's growing electricity import forecast relies on the UK's wholesale electricity prices retaining a premium to those in neighbouring markets. The premium is caused by a number of factors, most notably: continued oversupply in neighbouring countries, a higher UK carbon tax, a relatively high reliance on gas for power generation and the (currently) limited interconnection with neighbouring electricity markets.

There are a number of possible scenarios that could lead to a reduction in the UK's electricity price premium - for example - a more rapid coal phase-out in Germany or additional carbon taxes being introduced on the continent.

We remain hopeful that other EU countries will also implement higher carbon prices; so far the Netherlands has already committed to a carbon floor price of €18 in 2020 rising to €42 in 2030. There are live conversations in both France and Germany on national carbon pricing. This would go some way to reducing the UK price premium and the availability of interconnectors - existing gas would run harder.

Brexit brings its own risks. Current energy policy sets the UK on a path to meeting ~20% of electricity demand with imports throughout the 2020s, up from 6% today. In the current political climate, it is hard to envisage a scenario where this policy remains completely unchallenged over the next few years, especially if interconnector development prevents the construction of new UK-based power generating capacity.

Political risk is not confined to the UK; the French energy regulator (CRE) recently stated that it "*considers that it is not in a position to decide whether any new interconnector project between France and the United Kingdom is beneficial to the European community before the withdrawal conditions of the United Kingdom from the European Union are clarified*".[15] This ruling does not impact

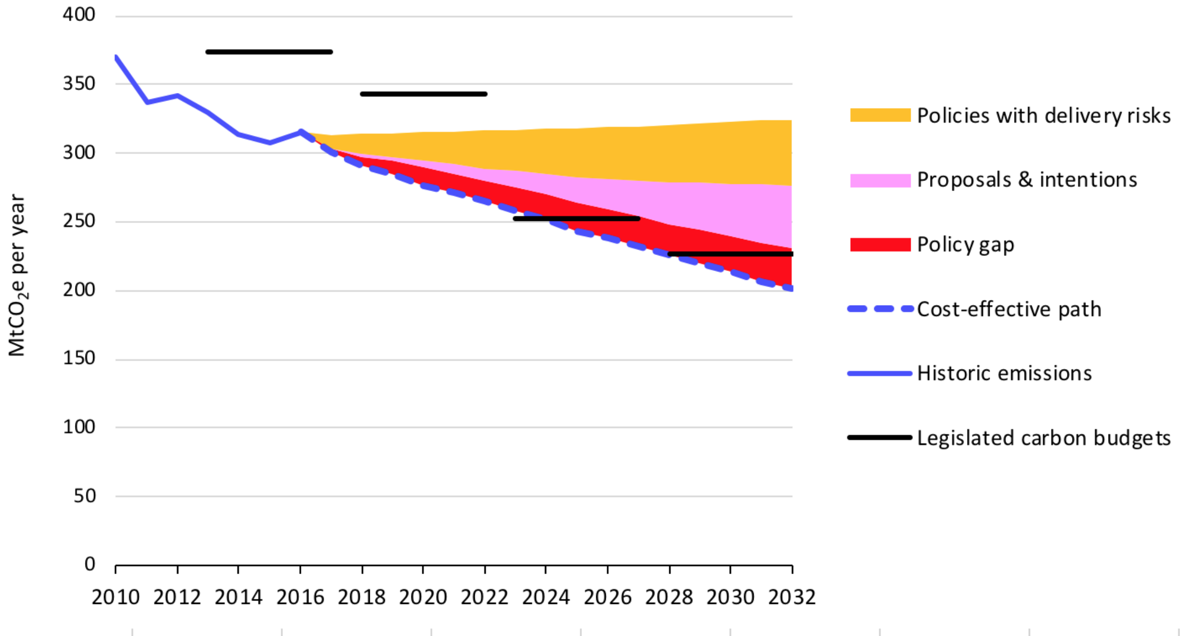
[14] *Pg. 9 The compatibility of UK onshore petroleum with meeting the UK's carbon budgets (March 2016) Committee on Climate Change*
[15] *Deliberation of the Energy Regulatory Commission (Nov 2017) CRE*

the IFA2 and Eleclink projects which have already been approved, however, the less developed UK-France projects look increasingly likely to suffer delays, which could reduce availability of imports.

In a scenario where imports did not grow, and gas was required instead, then this would increase carbon emissions by ~ 70MT by the end of 2025. This is larger than the entire policy shortfall (10-65MT,[16] see figure 10 below) in the Clean Growth Strategy that the Government must address to meet the 4th and 5th carbon budgets.

It is therefore imperative that the UK Government takes steps to reduce the risk of this unintended gas burn.

**Figure 10. Remaining gaps to the fourth and fifth carbon budgets (non-traded sector)**




*Source: Committee on Climate Change.*

## Nuclear

Electricity generation from nuclear power stations is expected to decline between now and 2025. Some existing reactors will reach the end of their planned lifetimes in the early 2020s and the first of a new generation of reactors (Hinkley Point C) is not due to be commissioned until late 2025. It is possible that the existing nuclear fleet could remain open for longer than expected (requiring Government approval and safety clearance from the Office for Nuclear Regulation) and this would lead to a large reduction in gas running hours. Maintaining nuclear output at current levels would save ~20MT of carbon emissions versus the current forecast to 2025 alone.

Beyond 2025, the Government assumes a large build programme of new nuclear plants. The drastic falls in the price of renewables and storage technologies over the past few years have increasingly put this plan on questionable economic footing, especially given the nuclear industry's recent history of project delays and cost overruns. In addition, it is clear to see from the Hinkley Point C process that additional plants may not be agreed and subsequently built on time. If the Government decides to change tack,

[16] *An independent assessment of the government's Clean Growth Strategy (Jan 2018) CCC*

replacing at least some of the planned new nuclear with renewables, it will need to start accelerating their deployment imminently if it is to avoid breaching the carbon budgets.

## Renewables

The Government's renewable growth forecasts are conservative and reflective of costs very much higher than were achieved in 2017. Studies show that new onshore wind could now be delivered at no additional cost to consumers[17] (i.e. at the long-term wholesale power price) - and would be 'key' to lowering UK industrial electricity prices. However, recent Governments have not supported this technology, with the 2017 Conservative manifesto stating that it did not believe that *"more large-scale onshore wind power is right for England"*. The Government's forecast reflects this policy, their latest projections show no growth in onshore wind from 2019.[18]

There is now exceptionally broad public support, in both urban and rural communities, for the UK's lowest cost form of power generation.[19] To cut the consumer cost of electricity, and to more rapidly tackle gas emissions, it is vital that the Government lifts the current moratorium.

We believe it is high time for a policy shift on this issue: where there is support in the local community, onshore wind should be allowed and encouraged. Coupling this with a more constructive regime for solar, where Government support has been scaled back dramatically in recent years, would provide a much-needed boost to both industries. Growth in these technologies could progressively mitigate some of the risk of policy failures elsewhere (such as interconnectors and nuclear, discussed above), achieving significant growth in the early 2020s, and diversify the UK's renewables mix from its current singular focus on offshore wind. Meanwhile decisions to accelerate offshore wind support now would allow the technology to contribute further in lowering gas demand after 2025.

## Demand

Electricity demand is forecast to remain broadly static between now and 2025. There are a myriad of different inputs to the forecast each with their own uncertainty, the most prominent of these are economic growth, energy efficiency measures and the uptake of electric vehicles.

On electric vehicles, in National Grid's most progressive scenario ("Two Degrees") from its 2017 *Future Energy Scenarios*, annual demand from electric vehicles is projected to increase by ~ 10TWh by 2025 - which equates to about 3% of total electricity demand.[20] Independent modelling by Vivid Economics for WWF suggests that even if the government moves forward the ban on the sale of new internal combustion engine vehicles from 2040 to 2030, total demand from EVs would be just 12.7TWh in 2025.[21]

Latest data suggest that electrical vehicle growth is behind the "Two Degrees" scenario; while rapid acceleration is clearly a possibility, the magnitude of the figures suggest that over this short time horizon (to 2025), electric vehicle deployment is unlikely to materially impact the conclusions of this report.

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[17] *An analysis of the potential outcome of a further 'Pot 1' CfD auction in GB (April 2017) Baringa*
[18] *Control for Low Carbon Levies (Sept 2017) UK Government*
[19] *0.1% of 16-44 year olds 'strongly oppose' onshore wind (Nov 2017) Carbon Commentary*
[20] *FES 2017 Documents (July 2017) National Grid*
[21] *Modelling not yet public.*

## Scenario Analysis

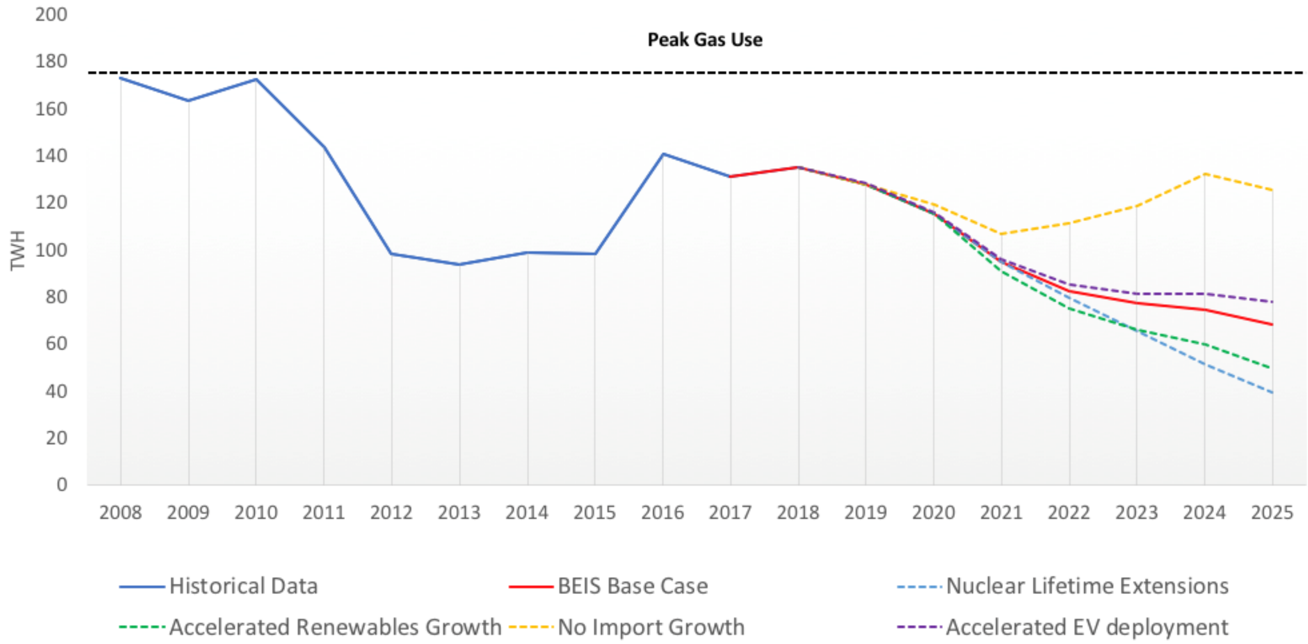
It is clear from the discussion that there are a number of uncertainties that could lead to significant deviations from the Government's forecast for gas use in the electricity system in 2025.

We have modelled the impact of these uncertainties in four alternative scenarios:

- *No Import Growth*: interconnector imports are held at the 2016 level.
- *Accelerated Renewables*: 1GW of extra onshore wind and solar added annually from 2020.
- *Nuclear Lifetime Extensions*: no nuclear retirements before the end of 2025.
- *Accelerated Electric Vehicle Uptake*: the commitment to end the sale of conventional petrol and diesel cars and vans is brought forward to 2030 from 2040. This reflects WWF's current campaign position on the decarbonisation of vehicles.

Please see appendix 2 for further details on the modelling. The projected gas use in the electricity system in each of these scenarios and in the BEIS base case are shown in figure 11.

**Figure 11. Gas use has peaked but the rate of future decline is less certain**




*Source: BEIS & Sandbag Calculations. Please see appendix 2 for more details on the scenarios.*

With the notable exception of *No Import Growth* all of the scenarios show a sharp reduction in gas use by 2025 but differ on the absolute level. While we view *No Import Growth* as the least likely of all the scenarios, it shows that the Government cannot be complacent in its assumption that the electricity sector will be the key tool for further reducing UK carbon emissions.

The actual path the UK takes will have a significant impact on the running hours of the legacy gas fleet and any new capacity required to replace coal, this is quantified in the modelling in the following chapter.

# Chapter 3 - How often will power plants run in 2025?

In Chapter 2, we explored how much electricity will be required in 2025 and how it is likely to be sourced. We highlighted how the growth in renewables will cause conventional fossil fuels' share of the electricity mix to decline.

The UK currently has a large fleet of gas power stations, many of which will still be operational in 2025. In this chapter, we explore how often these legacy gas power stations will need to run, whether any new power generating capacity is required to meet demand once the coal stations have retired and if so, how often this new capacity will be required to run.

To investigate, we built a simple model for hourly electricity generation in Great Britain in 2025.[22] We used this to forecast the 2025 running hours of the legacy gas capacity and any new capacity required to meet demand.

**Key assumptions:**

- Coal output is assumed to be zero.
- Renewables growth as per the Government's capacity addition assumptions[23] + Sandbag forecast for further growth as a result of 2019's CFD auction.
- Imports, demand & nuclear in line with BEIS forecasts.
- Normal weather conditions.[24]

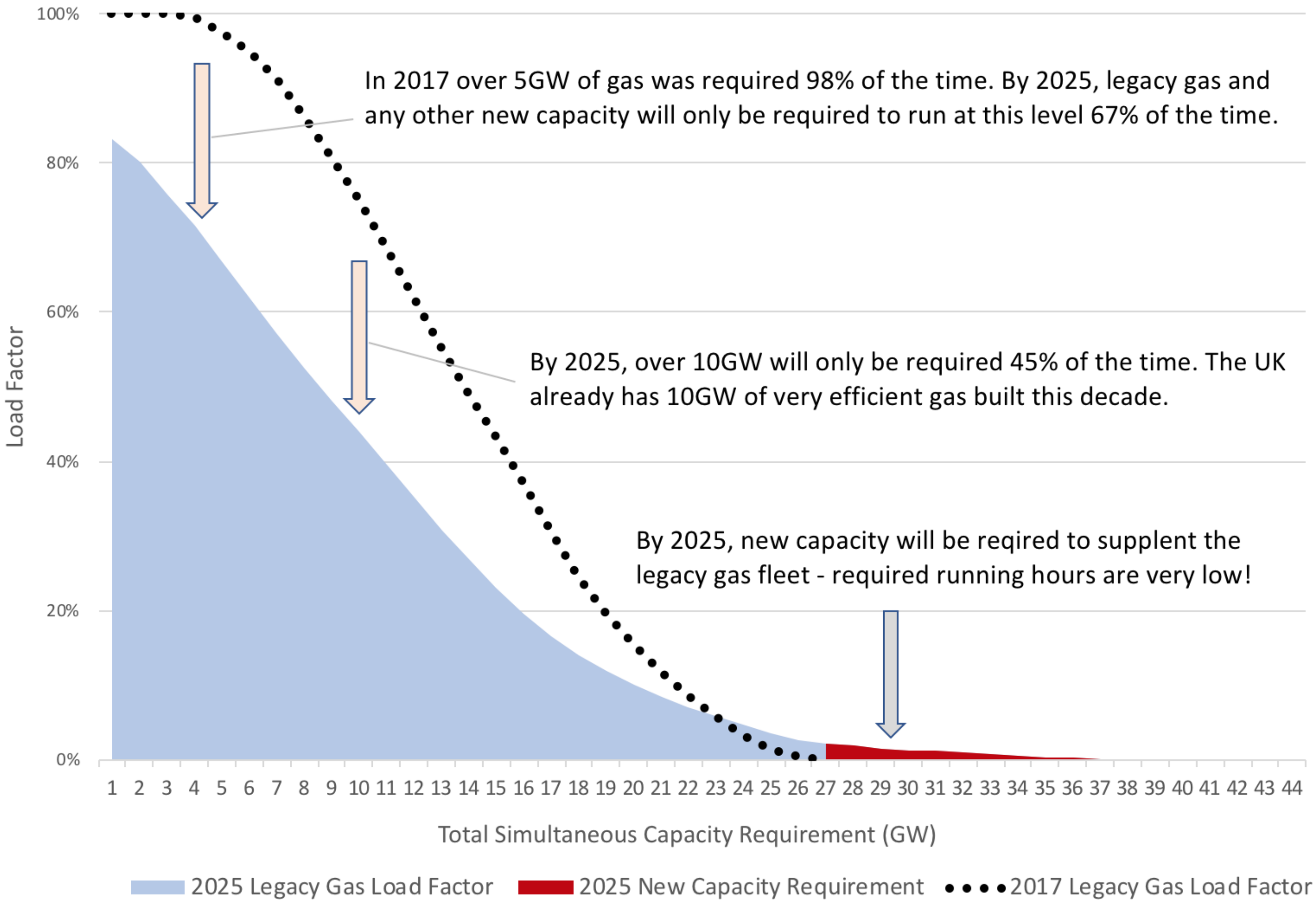
For more details on the modelling and the assumptions used, please see the appendix.

The results are used to generate a *load duration curve* - this indicates how many hours in a year the cumulative capacity requirement exceeds a certain level. We do this with a measure called *load factor* - this represents the percentage of hours in a year that a power plant is running at maximum capacity, 100% indicates 24x365 operation. The output of the analysis, is shown in figure 12 with 2017's historic load duration curve for legacy gas capacity displayed for comparison.

---

[22] *Due to constraints on available data we have excluded Northern Ireland. Northern Ireland's electricity grid is very small (2-3% of total UK demand), so this will not materially impact the conclusions.*
[23] *The Government's forecast collates data from BEIS, the CFD register and Ofgem's FIT administrative data. This results were published by HMRC in the recent Control for Low Carbon Levies document.*
[24] *The base data is from 2016 - temperatures were slightly above average (0.5C) but wind speeds were slightly below average (-0.5 knots) - we calculate that the impacts are broadly offsetting.*

**Figure 12. 2025 Legacy Gas + New Capacity Load Duration Curve vs. 2017**




The model identifies four key details:

- Overall running hours for the legacy gas fleet are much lower in 2025 despite coal's closure.
- By 2025 new capacity will need to be built to supplement the legacy gas fleet but its running hours will be very low.
- There is a large reduction in the number of plants required to run *baseload*.[25]
- The most efficient stations (those dispatched first and therefore to the left of the chart) see the largest reductions in their running hours.

Of the legacy gas fleet, we expect 27GW will still be operational in 2025.[26] Assuming legacy gas is dispatched first, from the chart above it is clear that in a normal year, required running hours of any new capacity above this level will be very low. In our base case scenario, the average load factor of the new capacity is less than 1% and no single unit has a required load factor higher than 2% (175 hours per year). **Therefore, given good use of the legacy gas fleet, any new gas capacity built once coal is phased out will only be required to run very infrequently.** We'll discuss the emissions impact of this new capacity in Chapter 4.

The results also show that only approximately 5GW of gas capacity will be required to run baseload in 2025. The UK has almost 10GW of highly efficient combined cycle gas turbines (CCGTs) built in this

[25] *Here defined as running more than 70% of the hours in a year.*
[26] *De-rated CCGT & CHP with 2021/2022 capacity market contracts - excluding plants without National Grid operational metering.*

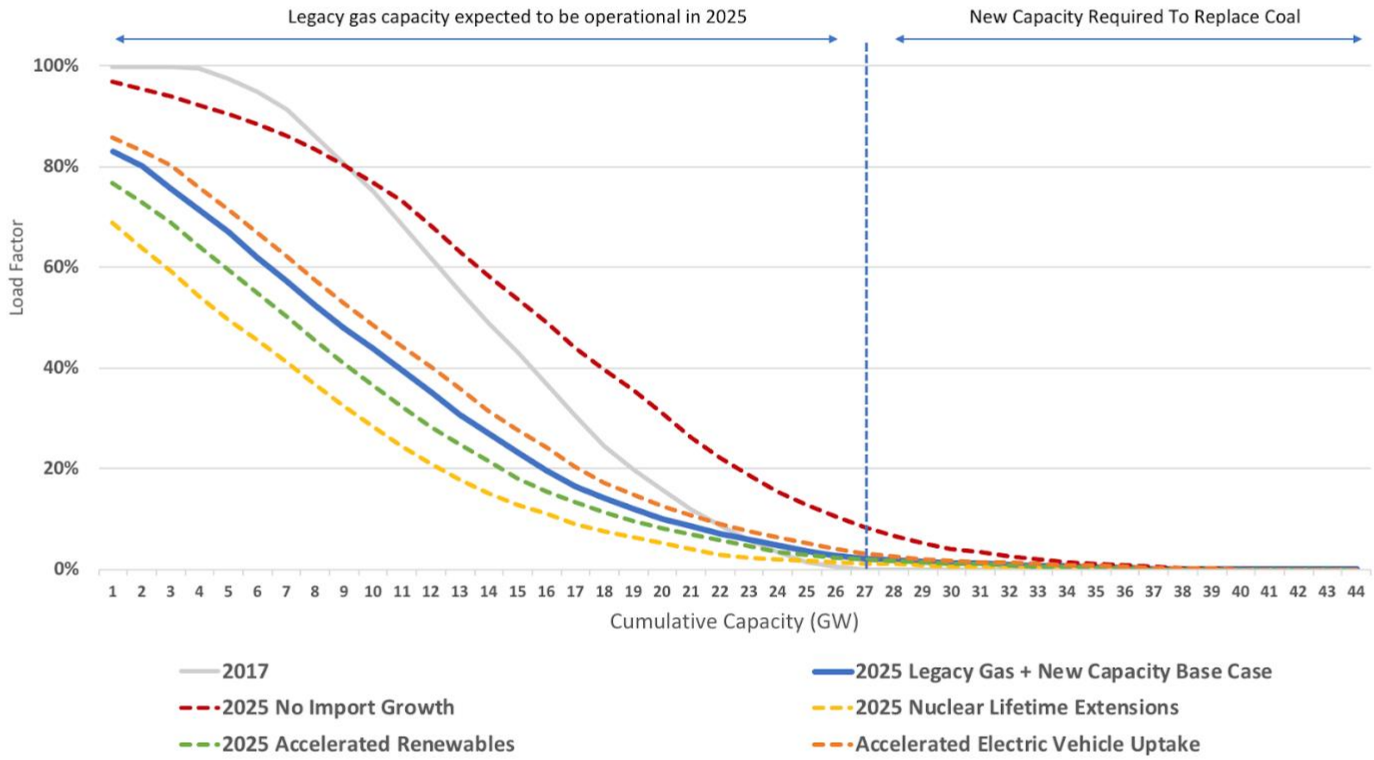
decade, these are likely to remain operational well into the 2030s. ***The UK therefore already has all the baseload gas capacity it is likely to need and does not need to build any new large gas plants***.

## Scenario Analysis

As discussed in the previous chapter there are a number of key uncertainties that could impact the assumptions in our modelling. Here we attempt to quantify the impact of those uncertainties on the running hours of the legacy gas fleet and any new-build capacity in 2025.

We re-ran the hourly model with our four different scenarios - *No Import Growth*, *Accelerated Renewables*, *Nuclear Lifetime Extensions* & *Accelerated Electric Vehicle Uptake*, the outputs are shown in figure 13. Please see Appendix 2 for the full scenario assumptions.

**Figure 13. Scenario Analysis for 2025 Legacy Gas & New Capacity Load Duration Curves**




*Source: National Grid Data & Sandbag Calculations*

As would be expected the chart shows that the running hours of the legacy gas capacity and new-build capacity increase in the *No Import Growth* & *Accelerated Vehicle Uptake* scenarios and fall in the *Accelerated Renewables* & *Nuclear Lifetime Extension Scenarios*, however the magnitude of the deviations from the base case scenario differ considerably.

The *No Import Growth* scenario is the only scenario (including the base case) where the running hours of the legacy gas fleet increase vs. 2017's levels; consequently, this scenario poses the greatest risk to the UK's climate targets from higher than expected gas burn.

The *No Import Growth* and *Accelerated Vehicle Uptake* scenarios show the largest numbers of hours where demand cannot be met from the legacy gas fleet and therefore must be met with generation from new-build capacity. However, the total running hours for the new-build capacity remain low - no new-build power generating unit is required to run for more than ~**500** hours per year, most will run considerably less.

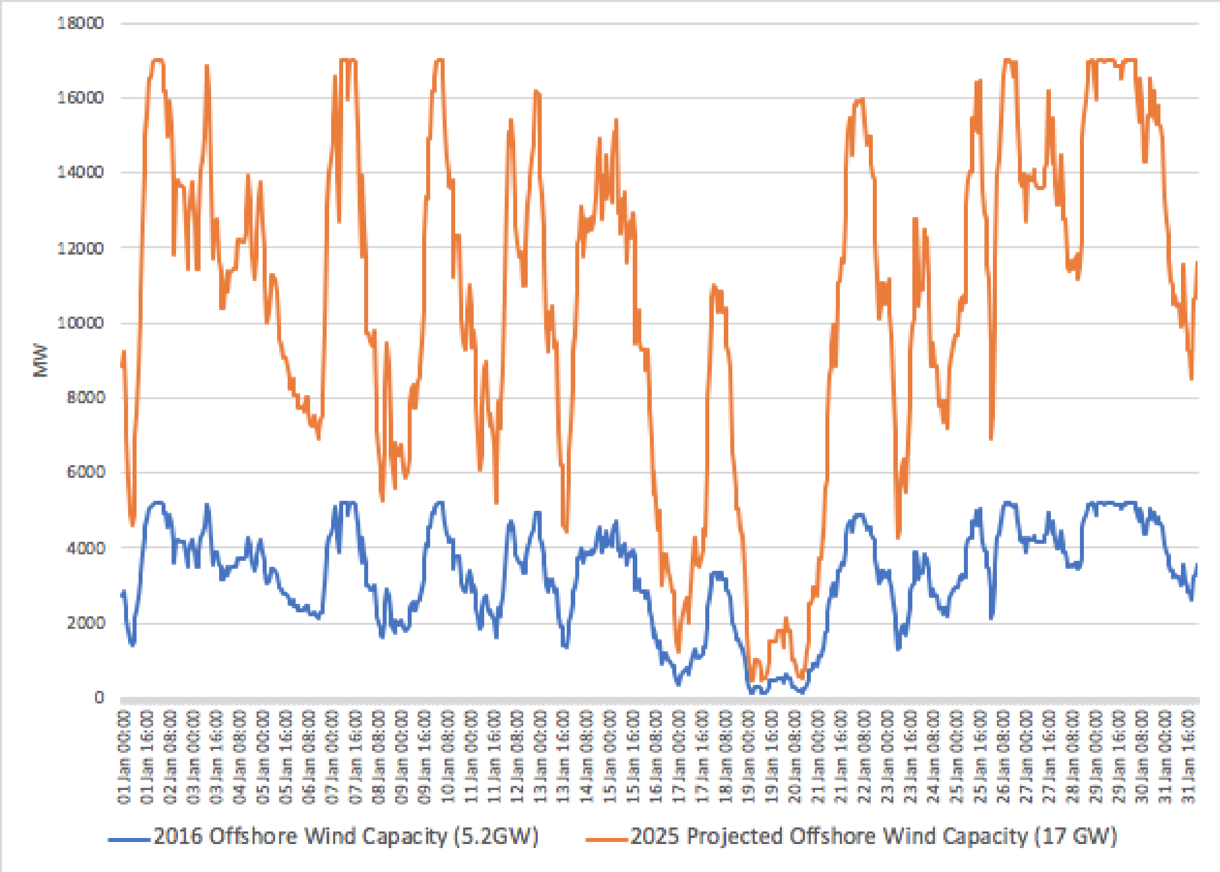
**If gas use sinks - why is there still so much gas capacity?**
Despite the huge growth in renewables the modelling suggests that the UK will still need a large number of gas power stations connected to the grid in 2025, however, only a few will be running continuously, and many will sit idle for long stretches in the year. In this section we explain why the UK needs so much gas capacity if much of it rarely operates.

As wind generation makes up a rising share of the UK's electricity generation it will drive down gas' running hours and the UK's carbon emissions. However, there will be instances when prevailing weather patterns cause the wind to drop, backup generation will be required to ensure the lights stay on at these times. The backup generation requirement remains broadly unchanged almost regardless of how much offshore wind you install.

To illustrate this point, in figure 14 we display the output from offshore wind in the UK in a typical winter month, we have chosen January 2016. The chart shows the expected output[27] from all offshore wind turbines under two scenarios: first the installed capacity available in 2016 (~5.2GW), the second with the installed capacity we expect to be available by 2025 (~17GW). While the average output from 17GW is clearly much higher, during the highlighted wind lull, both the 5.2GW and 17GW capacities deliver approximately the same amount of electricity (not much at all). Therefore, the required backup generation is broadly unchanged in both scenarios.

*[27] Historical wind speeds at five offshore wind sites, chosen to give a good coverage of the planned and existing offshore wind installations, were applied to an industry standard 8MW turbine power curve to create the expected load factor at each locations. The load factor was than averaged across all locations and applied to the installed capacity to generate an approximation for expected UK offshore wind output.*

**Figure 14. Offshore wind generation in January 2016 under two capacity scenarios**




Despite impressive cost reductions in recent years, lithium batteries are unsuited to provide backup for multi-day wind lulls (attempting to do so would be inefficient and prohibitively expensive[28]). Other new storage technologies show promise but are further away from full commercial deployment. Therefore, in 2025 we expect much of the backup capacity will be provided by existing gas. In the longer term to ensure the UK continues to meet its carbon budgets a low-carbon replacement will need to be found - this is one of the key challenges of the UK's energy transition.

[28] *Replacing 17GW of wind for just 1 hour would require ~ 130 of Tesla's recently installed 100MW/129MWh [South Australian batteries](). At current exchange rates this would cost ~£4.5bn. Even adjusting for expected cost reductions and economies of scale - expanding the capacity to provide a meaningful backup for multi-day wind lulls is a non-starter.*

# Chapter 4 - What capacity replaces coal?

The UK's Capacity Market went live from October 2017, and at that point there were seven coal power plants that received contracts, therefore playing a role in making sure the lights don't go out. Generation will increasingly come from renewables, reducing emissions and electricity costs, but backup will come from technology contracted in the Capacity Market. Throughout the energy market's transition, the Capacity Market will ensure that there is always enough supply available to meet demand, even on a cold, windless evening in the depth of winter. The Capacity Market determines what capacity is built to replace these seven coal plants.

On 9 February 2018, the results of the latest Capacity Market auction were published. We have analysed all four auctions to show how much coal capacity has been replaced already, and what has replaced it.

**By October 2021, there will only be two coal plants left with capacity contracts. This means that five coal plants - Eggborough, West Burton, Aberthaw, Cottam and Fiddlers Ferry - have effectively been replaced already.**

Eggborough has announced that it will close by September 2018;[29] the other four coal plants have yet to announce a closure date. However, it is likely they will close by October 2021, since they are financially reliant on capacity payments, and it is unlikely that they would get a one year contract in the 2021/22 auction because there is likely very little capacity left to contract.[30] Unsurprisingly, the capacity of these five coal power plants matches the replacement capacity, which we are able to track through auction results.

***So far, no new large gas plants have been built as a result of the Government's coal phase-out legislation. Instead*, our analysis shows the five coal plants were replaced with:**

- **885MW of new batteries**. Back in 2016, a National Grid auction for a service called "Enhanced Frequency Response" kicked off interest in lithium batteries, and it has grown ever since. Despite changes to the de-rating in 2018, 364MW of batteries won 15-year contracts in the recent auction in February 2018.
- **1,268MW of new demand-side response:** This winter there is only 135MW of DSR contracted in the capacity market, but this has risen to 1,403MW by the 2021/22 auction.
- **3,100MW of new interconnection**: Three new interconnectors are either under construction or due to be imminently: the Eleclink and the IFA 2 to France, and the NEMO link to Belgium.
- **380MW of new pumped storage and energy from waste**: Ffestiniog (173MW) won a 15-year contract to refurbish the pumped storage units 1 and 2. A new energy from waste plant is also being built.
- **3,337MW of new smaller gas**:
    - **376MW Combined Cycle Gas Turbine (CCGT)**. A small CCGT refurbishment of the mothballed King's Lynn CCGT.
    - **400MW Open Cycle Gas Turbine (OCGT)** dominated by the 299MW site at Spalding.
    - **2,560MW of small gas engines**. These are analysed in more detail below.
- **850MW of new diesel**: 850MW of small diesel peaking plant were awarded 15-year contracts. Defra has now closed the loophole that excluded them from air pollution limits. The additional investment required to comply with pollution limits has reduced diesel's competitiveness in the

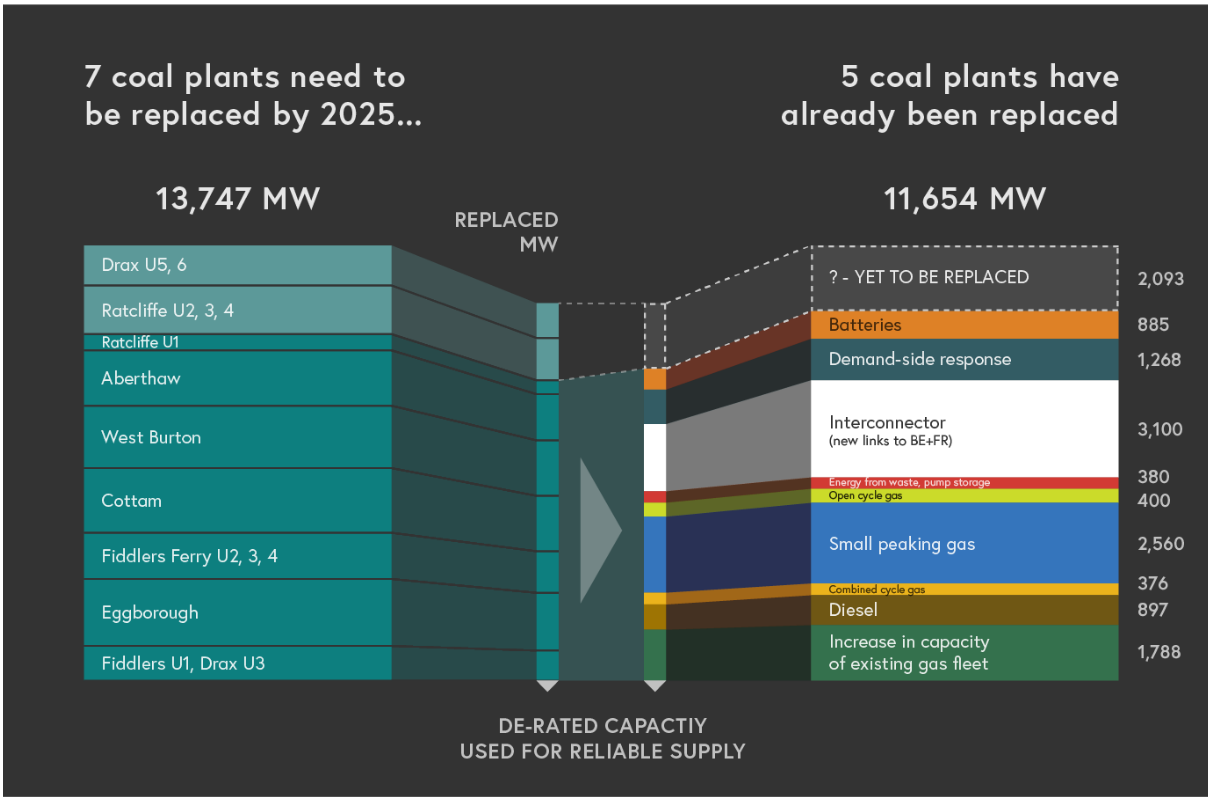
[29] *Eggborough coal plant to close before next winter (Feb 2018) The Telegraph*
[30] *Although there was 400MW set aside for the T-1, a Drax biomass coming online means that there may be no need to auction for more capacity.*

auctions - as a result no contracts were given in the recent auction (2021/22), and only a maximum 20MW of contracts were given in 2020/21. *Therefore, we do not expect any further new diesel capacity to be built* - the running hours (and therefore carbon emissions impact) of the new units that made it into the Capacity Market are likely to be low and will be constrained further by air quality limits by 2025.

- **1,788MW increase in existing gas.** Peterhead, a 1180 MW CCGT built in the 1980s looked like it might close when it failed to win a 2017/18 contract, however, it was successful in recent auctions and will remain open. Two CCGTs - Corby (407MW) and Barry (250MW) were in the 2017/18 auction but not in the 2021/22 auction. De-rating rules also changed which meant the existing gas fleet increased their auction capacity.

*NB: This analysis compared the differences between the 2017/18 T-1 auction and the 2021/22 auction T-4, and although there were coal units at Drax, Fiddlers Ferry and Ratcliffe that were not awarded capacity contracts in the 2017/18 auction, they were essentially outbid by new generation which came online early in 2017/18, and that is why we include both sides - the coal units, and the new build - on the graphic below.*

**Figure 15. Contracted capacity replacements to date on the UK Capacity Market**




Over the next four years, only 2.8GW more capacity must be contracted to replace the two remaining coal plants. Drax's 4th unit (0.6GW), which is not currently in the capacity market will convert to biomass and this will provide part of the requirement; and the competition for the rest of the capacity will be fierce - we do not believe market dynamics have materially changed, therefore technologies that have so far undercut large gas plants, with the notable exception of diesel, are likely to continue to do so. **As a result, it is likely that the UK will replace all 7 coal power plants without building any new large gas plants.**

## 4.1 - The likely winners

**Batteries**
Battery developers were dealt a blow at the end of 2017. Until then, all battery storage was valued equally, regardless of the duration for which each could deliver maximum power. Longer duration storage is more expensive to build, therefore the vast majority of installations to win 15-year capacity market contracts in previous auctions did not have a requirement to have more than 30 minutes of storage.

New analysis from National Grid showed that the mean stress event on the power grid lasts two hours, some events last much longer, but the large majority last less than four hours.[31] In response, *BEIS* announced that battery storage unable to deliver maximum power for four hours would have its net capacity derated[32] progressively as duration decreased, battery storage able to deliver for just 0.5 hours would have an ~ 80% reduction in eligible capacity payments. The derating factors are shown in figure 16.

**Figure 16. Capacity market de-rating factors for battery storage**

| Minimum Duration | 2018/19 T-1 | 2021/22 T-4 |
|---|---|---|
| 0.5 hours | 21.34% | 17.89% |
| 1 hours | 40.41% | 36.44% |
| 1.5 hours | 55.95% | 52.28% |
| 2 hours | 68.05% | 64.79% |
| 2.5 hours | 77.27% | 75.47% |
| 3 hours | 82.63% | 82.03% |
| 3.5 hours | 85.74% | 85.74% |
| 4 hours + | 96.11% | 96.11% |

**Source:** National Grid, Duration-Limited Storage De-Rating Factor Assessment – Final Report

Despite this change, 364MW of batteries still bid successfully for 15-year contracts in the recent auction in February 2018.

Battery costs are falling fast, analysis from Mckinsey[33] sees prices falling to $160/KWh by 2025 - less than half of today's levels.[34] If costs fall as expected (or faster) battery capacity will continue to grow.

**Demand side response (DSR)**
1,400MW won capacity market contracts in the 2021/22 T-4 auction, up from 135MW in the 2017/18 auction. So far, much of the DSR in the capacity market is provided by onsite generation, where consumers switch to backup fossil fuel generators to reduce demand on the grid. This will come with associated emissions, unlike turn-down DSR where customers reduce demand in return for payments from National Grid. However, the capacity market is unlikely to incentivise new-build on-site generation for DSR, given the maximum contract term of 1 year (as opposed to 15 years for a new-build classed as a generating unit). Strict pollution limits under the new EU Medium Combustion Plant

[31] *Duration-Limited Storage De-Rating Factor Assessment (Dec 2017) National Grid*
[32] *De-rated capacity is total generation capacity multiplied by a "de-rating factor" (always less than or equal to 1) - de-rating factors are based on the historical technical availability of each type of capacity at times of peak demand. They are a measure of the likelihood of the capacity type being able to deliver power when required.*
[33] *The new economics of energy storage (Aug 2016) McKinsey*
[34] *Levelized Cost of Storage (Nov 2017) Lazard*

Directive are applied to existing backup generators that participate in balancing services and will limit the operational hours and emissions impact of the existing fleet.

In future auctions, growth is expected in turn-down DSR as technology improves and businesses become more aware of the commercial benefits of participating. The Association for Decentralised Energy (ADE) conservatively estimated the total potential turn-down DSR capacity across the industrial, commercial and public sectors, to be ~**5GW** by 2020,[35] with a real impact on emissions. These figures suggest there is significant untapped DSR capacity which could displace coal in future auctions.

**Interconnectors**

As discussed in previous sections, there is a large pipeline of new interconnectors either in planning or under construction. With guaranteed revenues, interconnectors with cap & floor contracts are likely to bid aggressively, ensuring they receive a capacity market contract, regardless of the clearing price. There is 8.9GW of interconnector capacity with cap and floor agreements due online by 2023 *and not currently in the capacity market*.

The eligible capacity of each interconnector is determined on a case by case basis and takes into account both their technical reliability and an assessment of the likely future direction of electricity flows at times of stress. This is expressed as a de-rating factor for each interconnector, published each year along with the auction requirements and parameters.

**Figure 17. Constructed and planned UK interconnectors**

| Interconnector | De-rating factor T-4 (2021/2022) | Status T-4 2021-22 | Delivery Date | Connection Capacity (MW) | De-Rated Capacity | Cap & Floor? |
|---|---|---|---|---|---|---|
| IFA (France) | 63% | Contracted | 1986 | 2000 | 1260 | NO |
| BritNED (Netherlands) | 76% | Contracted | 2001 | 1320 | 1003 | NO |
| Moyle (Northern Ireland) | 14% | Contracted | 2002 | 500 | 70 | NO |
| EWIC (Republic of Ireland) | 59% | Rejected | 2012 | 500 | 295 | NO |
| Eleclink ( France) | 69% | Contracted | 2019 | 1000 | 690 | NO |
| NEMO (Belgium) | 75% | Contracted | 2019 | 1000 | 750 | YES |
| IFA2 (France) | 65% | Contracted | 2020 | 1100 | 715 | YES |
| NSL (Norway) | 85% | Did Not Register | 2021 | 1400 | 1190 | YES |
| Greenlink (Republic of Ireland) | n/a | Did Not Register | 2023 | 500 | n/a | YES |
| FAB Link (France) | n/a | Did Not Register | 2022 | 1400 | n/a | YES |
| Viking (Denmark) | n/a | Did Not Register | 2022 | 1400 | n/a | YES |
| Gridlink (France) | n/a | Did Not Register | 2022 | 1400 | n/a | YES |
| Neuconnect (Germany) | n/a | Did Not Register | 2022 | 1400 | n/a | YES |
| NorthConnect (Norway) | n/a | Did Not Register | 2022 | 1400 | n/a | YES |
| Aquind (France) | n/a | Did Not Register | 2022 | 2000 | n/a | NO |
| Channel Cable (France) | n/a | Did Not Register | UNKNOWN | 1400 | n/a | NO |

Looking ahead there is considerable uncertainty regarding the future de-rating factors applied to interconnectors. Policy changes or market dynamics (discussed in section 2.4) could reduce the reliability of interconnectors at times of stress, resulting in lower value attached to interconnection in future capacity auctions.

[35] *Flexibility on demand (July 2016) The ADE*

**Small peaking gas plants**
As discussed in the previous section, diesel peaking plants are no longer competitive in the auctions due to Defra's pollution constraints, however, despite the reduction in embedded benefits small peaking gas plants remain competitive; even with the low clearing price of £8.40/KW in 2021/22, 390MW still won 15-year contracts in the February 2018 auction, and over another 2GW was fighting for a contract.

**Open cycle gas plants**
In the latest 2021/22 auction, there were still three 299MW plants that unsuccessfully bid; so far only 299MW at Spalding and 100MW of smaller turbines have bid successfully for 15 year new-build contracts. These are likely to be more expensive than the small peaking gas plants but are still likely to undercut large CCGT gas due to their lower construction costs.

## 4.2 - Why are small gas peaking plants preferable to large gas plants?

There are two main types of gas plants that are vying to get built in the UK at the moment - small peaking plants and large gas plants.[36] Both technologies are far from perfect: they rely on fossil generation, and neither help to manage excess renewable electricity, unlike batteries and interconnector. However, it is worth understanding and comparing these two gas technologies, since there are so many developers bidding for contracts to support their construction.

Small gas peaking plants are cheaper and more flexible than large gas plants, but less efficient. This means they will emit more $CO_2$ per MWh than a large gas plant. However, provided peaking plant running hours remain low - their cost and flexibility benefit will far outweigh the increased emissions intensity.

[36] *There is a 3rd type: Open Cycle Gas Turbine (OCGT). However, the rush to build these has receded, and only 3x300MW plants bid into the capacity market in Feb-2018, most likely because they face stiff competition.*

| | Small peaking gas plant | Large gas plant |
|---|---|---|
| |  |  |
| ***Technical name*** | ***Reciprocating gas engine*** | ***Combined cycle gas turbine (CCGT)*** |
| ***How they work*** | Reciprocating engines use the expansion of hot gas to drive pistons, without using steam, much like a car engine. | CCGTs combine a gas and steam turbine to increase energy extraction. Waste heat from the gas turbine is used to drive a nearby steam turbine. |
| ***Size*** | **Mostly 2MW** (GE engines are 0.3 to 9.5MW). In the UK, they are often 10 side-by-side, say 10 x 2MW = 20MW. | **Mostly 800MW (0.8GW) and above**. Costing and efficiency below based on H-class Siemens/GE turbines. |
| ***Flexibility*** | Start-up = 2-3 minutes from a cold start.[37] | Start-up = 30-40 minutes when hot; 2-3 hours when cold (ramps up at 4-8% of full per minute).[38] |
| ***Capital cost***[39] | **£325/kW** (+ £8/kW annual maintenance) | **£460/kW** (+ £12/kW annual maintenance) |
| ***Design life***[40] | **10-20 years** | **20-35 years** (+ further extensions possible) |
| ***Deployment time*** | **1 year**[41] | **4 years** |
| ***Efficiency (LHV)*** | **38-48%**[42] ≈ 430-540Kg$CO_2$/MWh | **59-61% for H class turbines** ≈ 330-350Kg$CO_2$/MWh[43] |
| ***Capacity market in Feb-2018 for 2021*** | 2,620MW bid for 15-year contracts (390MW successful) | 13,200MW bid for 15-year contracts (none successful) |

Our analysis shows that *given good use of the existing fleet of large gas plants*, any small peaking plants built to replace coal will only be required to generate for a small fraction of the total hours in the year. In our scenario with the highest 2025 gas generation (with no electricity import growth), in an average year no peaking plant will be required to run more than ~ 500 hours per year, **most will run considerably less.**

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*[37] Electricity Generation Cost Update (2016) Leigh Fisher and Jacobs'*
*[38] For a state of the art CCGT on page 48 from Agora Energiewende's "Flexibility in Thermal Plants" (June 2017)*
*[39] The "low" cost scenario is used from research commissioned by UK Government; "low" was taken, as these are assessed as of 2016 and prices have most likely fallen further since. However, it is clear these costs are quite indicative and vary substantially site-by-site and with exchange rates.*
*[40] Also taken from Leigh Fisher.*
*[41] Slide 7 of Addressing the UK energy deficit (Feb 2018) Plutus PowerGen*
*[42] The record set by GE Power is 47.8%, but the least efficient GE reciprocating engines on sale are 38%. We suspect the majority of UK installations are around 40-42%.*
*[43] Real world performance will be lower if not operating baseload. CCGT, unlike small peaking gas, loses efficiency through starts and part-loading.*

At 500 hours per year, the difference in total carbon emissions between peaking plants and large gas plants is relatively small. If all the remaining coal stations (2.8GW) were completely replaced with small peaking gas plants, instead of large gas plants, emissions would be ~ 3MT higher over the course of their capacity market contracts.[44] **However, the cost of avoiding these emissions would be extraordinarily high.** Analysts forecast[45] that the Capacity Market will need to clear at ~£30/kW to ensure the construction of new large gas plants, ~£10/kW higher than recent clearing prices. As a result of the higher clearing prices, **the cost of the avoided carbon emissions would be ~ £300/tonne.**[46]

Therefore, where a fossil fuel capacity requirement arises from coal's phase-out, small peaking plants offer a much better deal for energy consumers without materially impacting the UK's climate objectives.

Small peaking plants have additional benefits over large gas plants:

**Flexibility:** quicker and lower startup costs make them more suited to respond to changes in intermittent renewable output.

**Deployment time:** reduced engineering complexity significantly cuts deployment time, in a rapidly evolving energy market - small peaking plants are better placed to respond to unforeseen circumstances.

**Reduced lifetime**: these gas plants are intended as a short-term fix until technology is in place to completely decarbonise the power sector. A large gas plant has a design life of 20-35 years, which means it is still generating well into the 2030's when the UK carbon budgets will struggle to justify much gas generation.

**However…**

The carbon footprint of small peaking plants depends on how they are implemented and how they run. Our analysis for 2025 assumes existing large gas plants are used preferentially to small peaking plants. However, current market design may cause peaking plants to displace more efficient existing large gas plants in the merit order in some hours, leading to higher carbon emissions than necessary. If the UK continues installing small peaking gas, a better policy framework is required to ensure they are used sensibly.

Here is a list of considerations:

- **Market design**: there are two issues that may cause small peaking plants to artificially overtake efficient gas plants in the merit order, leading to overall higher carbon emissions. These will need further scrutiny.
  - *European Emissions Trading Scheme (ETS) Rules*: combustion plants smaller than $20MW_{th}$ (~8MW electrical) are not covered by ETS rules. A further loophole exempts plants from ETS rules if they are made up of individual generating units under a $3MW_{th}$ (~1MW electrical) threshold, operating in series - even if the total generating capacity of the plant subsequently breaches the $20MW_{th}$ threshold. It is unclear how many plants

[44] *Assumes a 15 year Capacity Market contract, load of 500h per year and emissions intensity of CCGT and small peaking plants of 350$KgCO_2$/MWh and 500$KgCO_2$/MWh respectively.*
[45] *Flexibility investment (Oct 2017) Timera*
[46] *Assumes all 2.8GW replaced in 1 auction incurring additional £500m of costs (all 50GW of capacity market participants receive an additional £10/kW for large gas to clear). A further £420m of cost arises from the £10/kW difference in capacity market strike price for the 2.8GW across the duration of a 15 year contract.*

currently exploit these loopholes; however, they clearly must be addressed to avoid favouring the very smallest and least efficient engines.
    - *Embedded Benefits:* small peaking plants are connected to the distribution network (embedded) and are therefore entitled to a number of benefits not received by the large gas plants connected to the transmission network. There are concerns that embedded generators may be excessively rewarded under the current market design. Ofgem has already moved to reduce the largest of these benefits, the TNUoS Demand Residual,[47] and has proposed a targeted charging review to examine the remainder,[48] which we welcome.
- **Efficiency**: modern small peaking plants are available in a wide range of efficiencies, from below 38% to almost 48%. Currently there are no safeguards in place to prevent developers from selecting the cheapest and least efficient engines. There would be less concern if these plants were used as a last resort, however this is not guaranteed given the current market design flaws detailed above. With stricter regulation it may be possible to reduce emissions without significantly increasing costs.
- **Use of waste heat**: we suspect that not much of the waste heat is used; there is an opportunity to utilise this, selling it to nearby businesses, reducing total emissions.

In implementing the UK's coal phase-out, the Government has proposed an *instantaneous* emissions intensity limit of 450g$CO_2$/kWh for solid fuels. Extending the Government's proposal to *all fuels,* while significantly lowering the threshold (to 1$MW_{th}$, in line with the Medium Combustion Plant Directive[49]) will address many of the issues raised above, while still allowing generators to meet their capacity market commitments through a critical peak derogation of ~500 hours.

**Recommendation**

**We propose that the instantaneous emissions intensity limit of 450g$CO_2$/kWh is extended to all fuels with a thermal capacity of over 1MW**, initially for new installations and subsequently for existing installations. Also, a critical peak derogation of ~ 500 hours should be applied - in line with current environmental permitting.

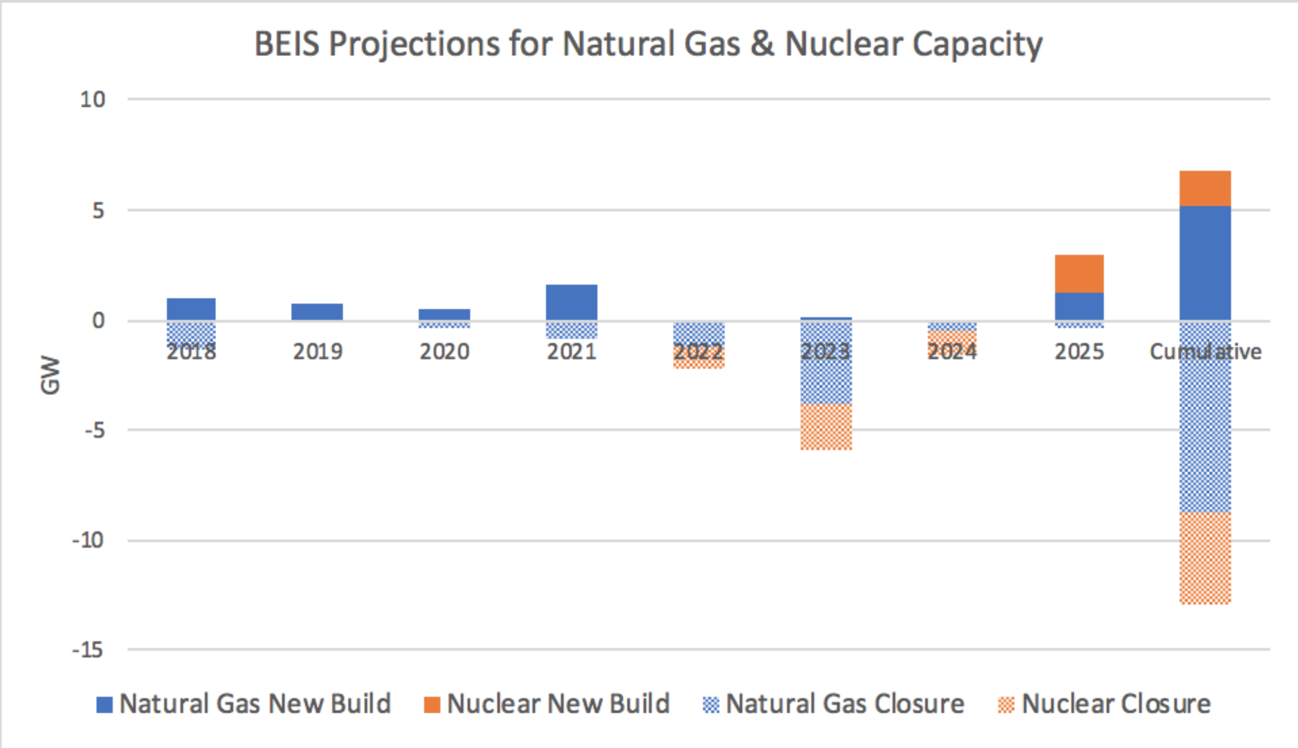
## 4.3 - What other capacity might need to be replaced?

The phase-out of coal will not be the only driver of changes to the UK's existing thermal generation fleet. The older nuclear stations and the gas plants built during the "dash for gas" in the 1990s will be reaching the end of their planned operational lifetimes.

Figure 18 shows the Government's recent forecast for the changes in gas and nuclear capacity between now and 2025. A dip in the available nuclear capacity in the mid-2020s and the projected closure of older CCGTs leads to a forecast requirement for ~ 5GW of new gas capacity.

**Figure 18. BEIS projections for Natural Gas and Nuclear Capacity to 2025**

[47] *Ofgem decides to lower payments to embedded generators (June 2017) Ofgem*
[48] *Spreading the costs of networks fairly (March 2017) Ofgem*
[49] *Medium Combustion Plant Directive (Nov 2015) European Commission*



*Source: BEIS 2017 Emissions Projections.*

However, the Government's projection that 8.7GW of gas capacity will close looks pessimistic, only Corby (407MW) is legally required to do so - by 2023 under its limited lifetime derogation in the Industrial Emissions Directive.[50]

Given the financial incentives on offer from the capacity market and the high costs of new-build gas capacity, it seems likely that at least some of the gas capacity the Government expects to close will, in fact, refurbish and undercut large, new-build gas in the capacity market. With the oldest CCGT in the fleet winning a 2021/2022 capacity market contract in the recent auctions - this scenario already looks to be underway.

**What is outlook for new large gas power stations?**
We have shown in the analysis that the UK's coal phase-out, announced in 2015, will not require any large new gas plants.

The UK will need some additional power generation capacity as a result of other trends in the energy market, such as the retirement of part of the old nuclear fleet, but it will not necessarily be gas and not need to provide baseload generation - it is required to ensure security of supply during periods of low renewables output. Much of this new capacity requirement could be avoided if the older gas power stations choose to extend their lifetimes. This will depend on the economic circumstances specific to each plant but on the evidence of recent auctions this scenario looks likely.

When genuine capacity requirements are identified, new-build gas must compete in the capacity market with other technologies such as storage, demand-side response and interconnectors. Ultimately the capacity market will decide which technology class can ensure security of supply at the lowest cost to consumers.

[50] *Industrial Emissions Directive (Nov 2010) European Union*

To meet the UK's climate targets, each year that passes implies lower total allowable running hours for a new gas plant. All else equal, gas developers will require progressively higher capacity market revenues. Concurrently, DSR & storage technologies are maturing, lowering costs. These divergent trends do not paint a promising outlook for new large gas power stations.

## 4.4 - Preparing for a gas phase-out

Government policy in this parliament will be key to avoiding the need for any new large gas plants, and for setting the trajectory towards a gas phase-out.

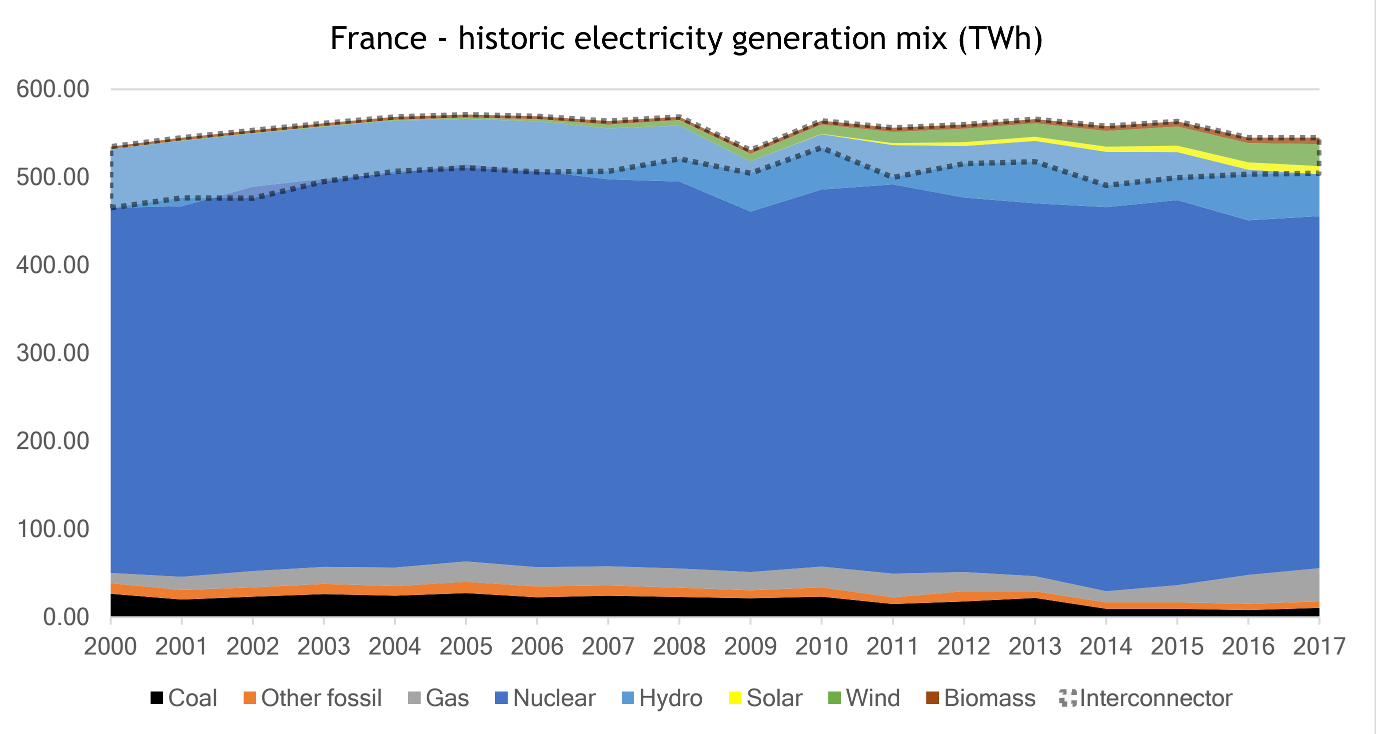
- **Entirely removing gas from the electricity system is only possible with significant innovation in:**
    - **interseasonal energy storage** (hydrogen, compressed air, longterm battery storage) and/or
    - **carbon capture and storage** (which with hydrogen would have a co-benefit of beginning the decarbonisation of heat).

- In the shorter term, **keeping gas use low throughout the 2020s will require**:
    - **Accelerated renewables deployment**, particularly in offshore wind.
    - **Increased large scale government investment in energy efficiency** to further drive down demand and consumer energy bills.

# Appendix 1 - The international picture

The UK electricity transition is not happening in a vacuum, and increased interconnection means increased reliance on electricity generation from elsewhere. This section reviews the countries with which interconnectors are operational or planned, and asks what are the risks and co-benefits from transitions in neighbouring countries? When the UK receives power, what is the likely carbon intensity?

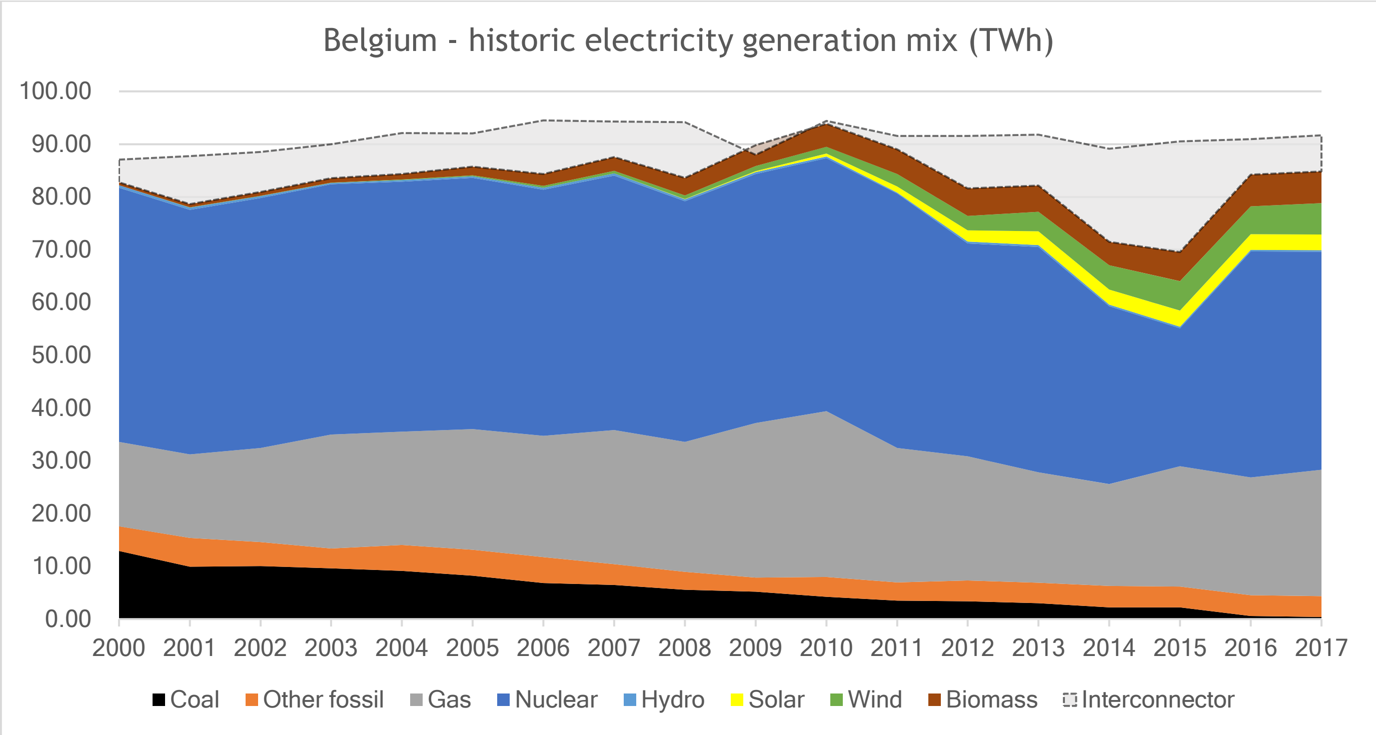
**France**




The UK currently has 2GW of interconnection with France, with a further 3.4GW in planning. The French electricity system is already almost totally decarbonised, regularly achieving carbon intensities as low as 30g$CO_{2eq}$/kWh. France's five remaining small coal plants are little-used but scheduled to be closed by 2021. President Macron has made clear France will prioritise coal phase-out and new renewables build over near term nuclear phase-out. However 2017 saw France's lowest nuclear generation this century as some of the fleet were closed over safety concerns. These are now coming back online, and the UK should for the most part be able to rely on receiving French power.

2017 was a record year for French renewables growth, which shows no signs of abating with an expansion into 3GW of offshore wind by 2023, as well as plans for 2GW of floating offshore wind and tidal projects. There should be further cost benefits for companies building offshore wind on both sides of the Channel.

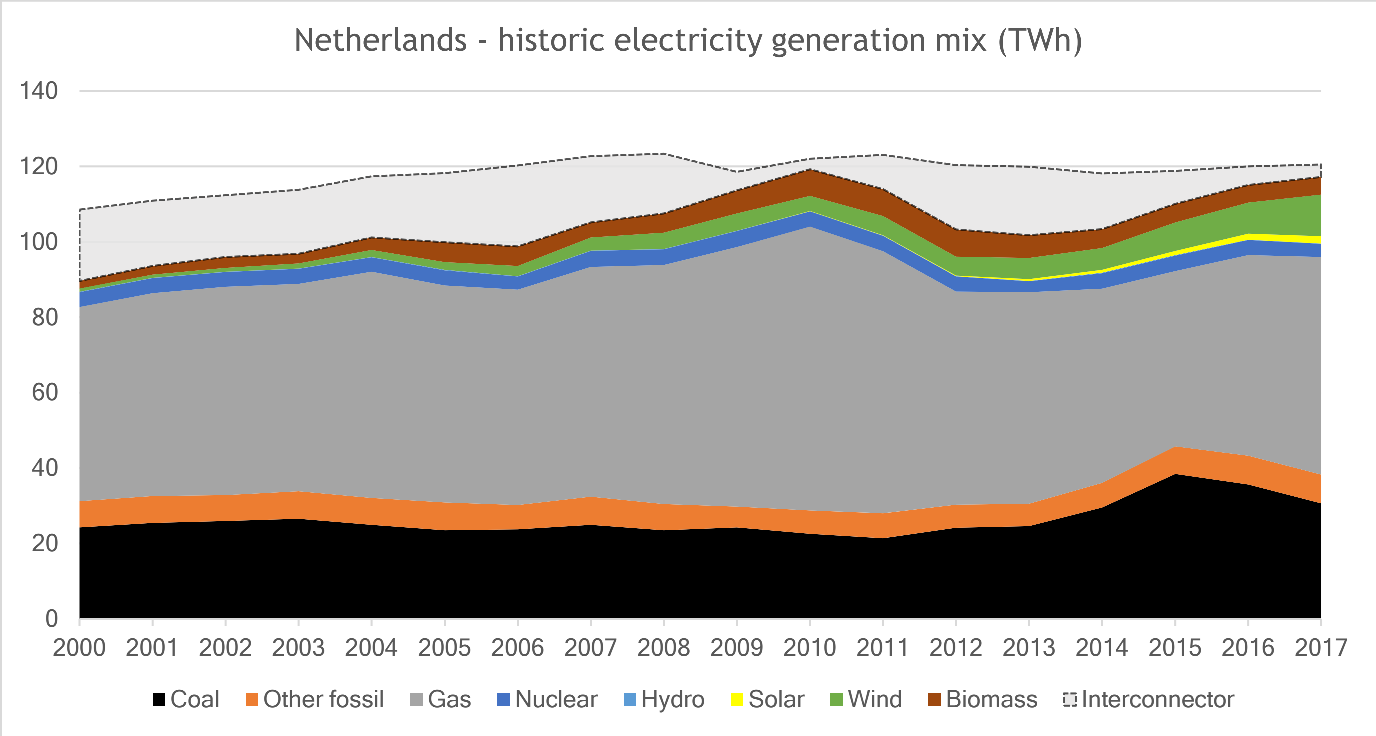
### Belgium




The Nemo 1GW interconnector will be completed with Belgium in 2019. Belgium's coal phase-out was completed in 2016, and the remaining mix of nuclear and gas power gives a lower carbon intensity than the UK's. To date, Belgium has mainly been an electricity exporter, but its planned nuclear phase-out by 2025 may change this.

Renewables continues to grow, for instance with 1.3GW of offshore wind [coming online by 2020](#).

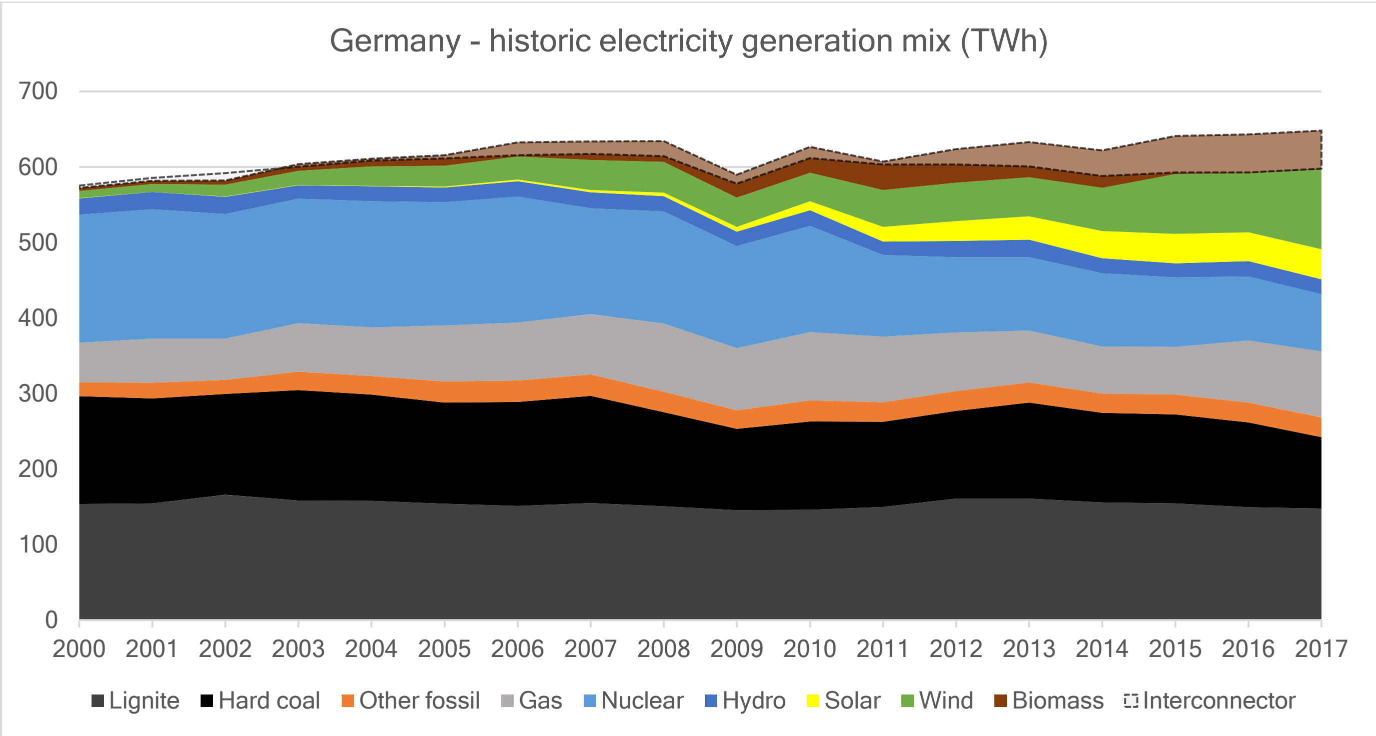
## Netherlands




The UK has a 1GW interconnector (BritNed) with the Netherlands, with flows mainly to the UK. The Netherlands electricity mix is more than 80% fossil fuels, bolstered by further imports of lignite power from Germany. Progress in reducing emissions has been weak to date, but last October's new coalition agreed to phase-out the Netherland's teenage coal plants by 2030.

1.3GW of offshore wind will come online by 2020, following the 1GW already installed.

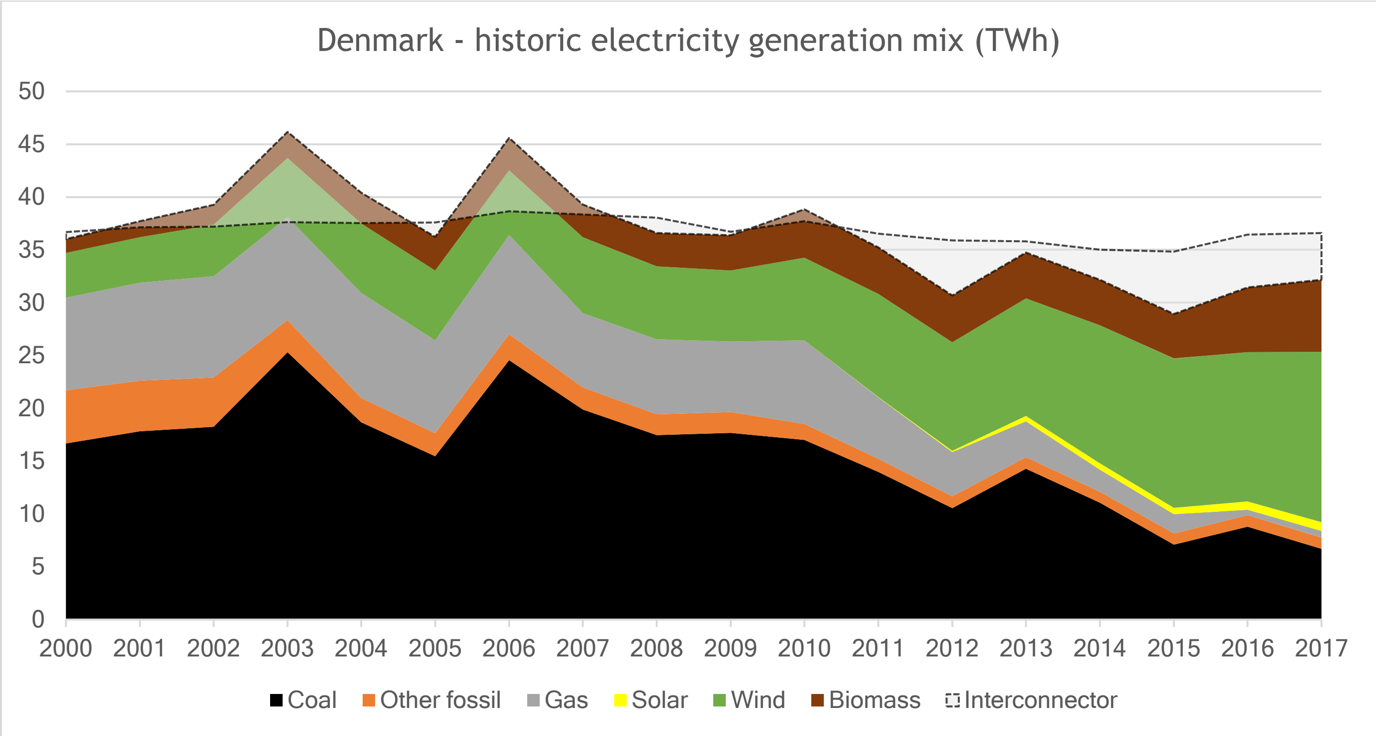
## Germany




The interconnector Neuconnect is planned to link the German and UK electricity grids in 2022, with a capacity of 1.4GW.

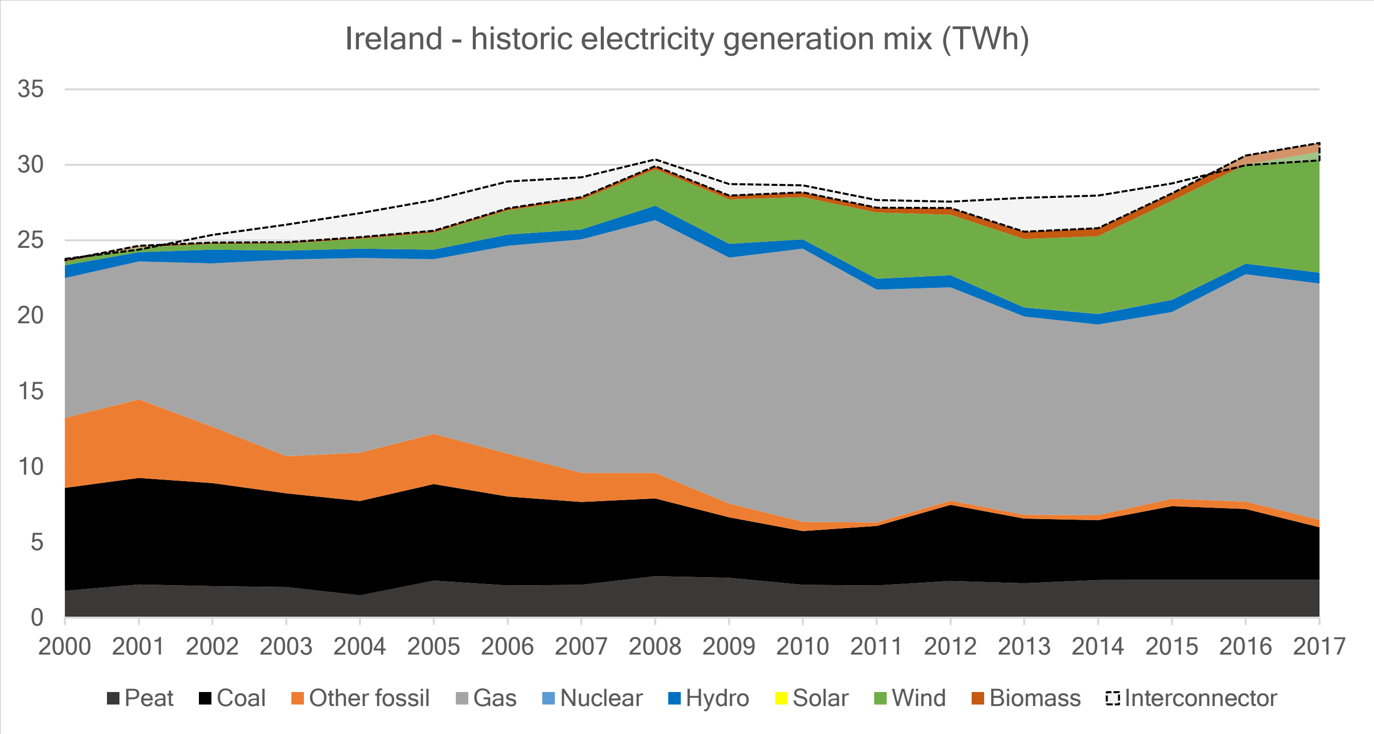
As shown in [a recent Sandbag report](), Germany has increasingly become an electricity exporter in recent years, fueled by overcapacity in lignite power plants, Europe's most polluting electricity source. Over the last decade, the German Energiewende has seen a phase-out of nuclear power (to be completed by 2022) and large growth in renewable generation, which to date have largely offset one another. Renewable growth is projected to continue, and the new coalition government have committed to announcing a coal phase-out date in early 2019.

## Denmark




A 1.4GW interconnector (Viking Link) between the UK and Denmark is planned for 2022. Last year, Denmark generated 74% of its electricity from renewables, alongside committing to phase-out its remaining coal plants by 2030, and is recognised by the IEA as “a global leader in decarbonising its economy”. Denmark is currently a net electricity importer. It has 1GW+ offshore wind already contracted to be built before 2020, and will easily exceed the EU Renewable Energy target.

## Ireland




The UK has 0.5GW interconnectors to both Ireland and Northern Ireland. The Irish interconnector (Moyle) continues to operate at half normal capacity due to subsea cable faults. Imports and exports with the UK have tended to balance.

Kilroot, the last coal plant in Northern Ireland, closes this year. Ireland's last coal plant, Moneypoint, is scheduled to close by 2025, but a number of high-emitting peat power stations remain without closure dates. Thanks to these, overall carbon intensity tends to be higher than that of the UK.

Ireland has weak investment in offshore wind, considering its location, with only one operational offshore wind farm, but has had steady growth in onshore wind, now up to a quarter of annual generation. Increasing electricity consumption has mainly eaten up the new renewables growth, rather than cutting into gas generation.

### Outside the EU

Further interconnectors are planned with Iceland and Norway.

# Appendix 2 - Hourly Model Assumptions

The model is simple, its basic premise is to scale the half-hourly generation data by fuel type from National Grid for 2016 (a broadly average year for wind and temperature[51]), to reflect the expected changes in capacity by 2025. The model then determines the volume of generation from the legacy gas capacity and any new capacity required to balance expected demand in every half hour.

National Grid's dataset is with respect to the transmission system, therefore embedded generation is part of the make-up of the demand figures. Using Entose's data on total onshore and offshore wind and solar output and National Grid figures we have unbundled embedded wind and solar output from the transmission connected demand figure and adjusted it accordingly.

The projections for the 2025 installed capacity by technology type are sourced from two government documents (with some adjustments detailed below). HMRC's Control for Low Carbon Levies[52] & BEIS's 2017 Energy & Emissions Projections.[53]

HMRC's *Control for Low Carbon Levies* sources data from BEIS, the CFD register & the Ofgem FIT administrative data and displays it in an easily usable format.

The baseline 2016 installed non-renewable capacity data is sourced from the BEIS Energy & Emissions Projections and the baseline installed renewable capacity data is sourced from the average 2016 installed capacity in BEIS's Renewable Energy Trends.[54]

The assumptions by technology class are listed below:

- **Coal:** output is set to 0.
- **Nuclear**: 2016's output is multiplied by the ratio of the 2025 forecast to baseline 2016 installed nuclear capacity (0.52).
- **Solar:** 2016's output is multiplied by the ratio of the GB 2025 forecast to baseline 2016 installed solar capacity (1.15).
- **Biofuel:** National Grid updated the way biofuel data is displayed towards the end of 2016, therefore a different approach was required. Small biofuel is held constant with decreases in landfill gas broadly offsetting gains elsewhere. Large biofuel output = forecast capacity * National Grid's biomass de-rating factor (0.87). Forecast large biofuel capacity is all biomass. Capacity = (Drax 1, Drax 2, Drax 3, Lynemouth, MGT Teesside & 100MW "other"). N.b Drax unit 4 is not included as limitations on ROCs for non-grandfathered units will prevent a material increase in renewables output from the site.
- **Onshore Wind:** 2016's output is multiplied by the ratio of the GB 2025 forecast to the baseline 2016 installed onshore wind capacity (1.3).
- **Offshore Wind:** 2016's output is added to the GB forecast generation from the expected offshore wind capacity additions operating under 2016's wind conditions. Forecast capacity addition is taken from HMRC's *Control for Low Carbon Levies* (8.83 GW) + the *Sandbag* assumption for the extra build as a result of the 2019 CFD (3 GW). Forecast generation uses an

[51] *Temperatures were slightly above average (0.5C) but wind speeds were slightly below average (-0.5 knots) - we calculate that the impacts are broadly offsetting.*
[52] *Control for Low Carbon Levies (Sept 2017) HMRC*
[53] *Updated Energy & Emission Projections (Jan 2018) BEIS*
[54] *Renewable Energy Trends (Jan 2018) BEIS*

industry standard 8MW turbine power curve and historic wind speeds at the sites of the new wind farms.

- **Interconnection:** 2016’s imports from the Netherlands & France are scaled up such that total imports (including Ireland) match BEIS’s import forecasts for 2025. Imports from Ireland are left unchanged.
- **Pumped Storage & Hydro:** unchanged from 2016’s figures.
- **Oil/Diesel:** existing embedded generation assumed unchanged. New installations are not explicitly modelled and are included as part of the required generation from the legacy gas fleet and any new capacity.
- **Battery Storage**: not explicitly included in the modelling as batteries makes up part of the generation requirement from the legacy gas fleet and new capacity.
- **Demand:** 2016’s demand is multiplied by the ratio of the 2025 forecast to 2016 demand (1.02).

## Scenario Analysis Assumptions

**BEIS base case:** taken from BEIS’s 2017 energy and emissions projections and adjusted to make forecast and historical data consistent. In BEIS's latest energy & emissions projections no generation was assigned to *Other Thermal* - this raises the gas forecast required to meet demand and creates inconsistencies in the historical and forecast data. BEIS have confirmed to Sandbag that they are investigating this issue. We have therefore reduced BEIS' forecast for gas use by 5.812 TWh (our approximation for 2017's Other Thermal figure) from 2018 to correct for this. This implicitly assumes *Other Thermal* generation remains constant across the forecast

The assumptions used in the four scenarios are listed below:

**No Import Growth:** interconnector supply is held at 2016’s levels. Gas output fills the gap left to meet demand.
**Accelerated Renewables:** an additional 1GW of solar and 1GW of onshore wind capacity is added each year from 2020. 33% load factor is assumed for onshore wind, 10% for solar. The additional renewables generation is assumed to reduce gas generation.
**Nuclear Lifetime Extensions:** no nuclear retirements take place before the end of 2025. The additional nuclear generation is assumed to reduce gas generation.
**Accelerated Electric Vehicle Uptake**: based on WWF’s campaign to end the sale of conventional petrol and diesel cars and vans in 2030 compared to 2040. The resulting additional electricity demand increases gas generation requirements. The additional electricity demand figures are sourced from the 2030 scenario in Vivid Economics’ independent modelling for WWF.[55]

[55] Ending Petrol and Diesel Vehicle Sales by 2030 *(March 2018) WWF UK*

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