E3G

**REPORT** NOVEMBER 2018

# INSIGHTS FROM THE UK COAL PHASE OUT EXPERIENCE:

## REPORT TO CHILE DECARBONISATION ROUNDTABLE

**CHRIS LITTLECOTT, LOUISE BURROWS & SIMON SKILLINGS**

**Cover image:** Autumn sunrise over Kingsnorth Power Station by ifor.griffiths
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## About E3G

E3G is an independent climate change think tank operating to accelerate the global transition to a low carbon economy. E3G builds cross-sectoral coalitions to achieve carefully defined outcomes, chosen for their capacity to leverage change. E3G works closely with like-minded partners in government, politics, business, civil society, science, the media, public interest foundations and elsewhere. In February 2018, E3G was ranked the fifth top global environmental policy think tank for the second year running. **www.e3g.org**

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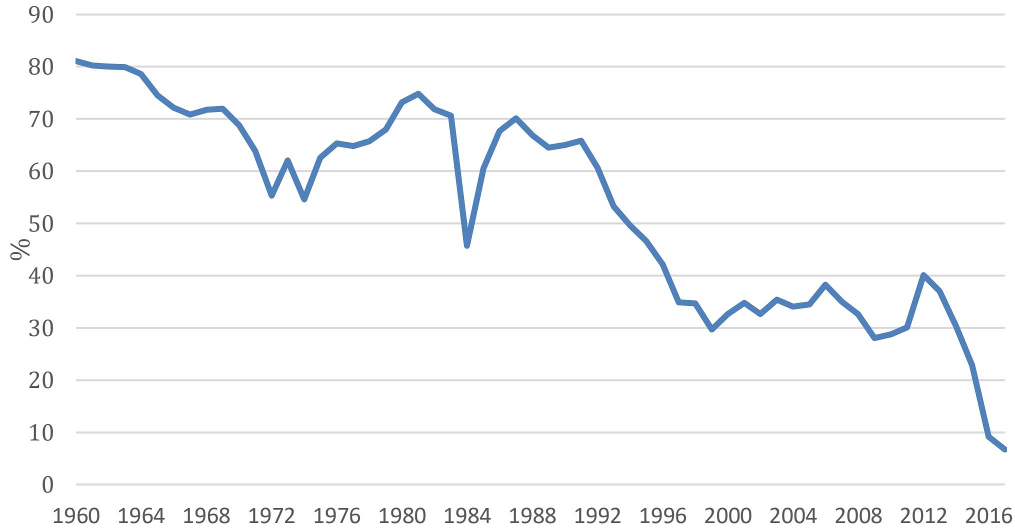
# EXECUTIVE SUMMARY

In November 2015 the UK government was the first to commit to a national coal phase out policy, which will see coal-fired electricity generation cease by 2025. But just three years earlier coal had provided 40% of electricity generation.[a] Historically, coal had been the dominant fuel in the UK electricity mix, providing 97% of electricity in 1950 and over 70% in the 1980s, as shown in Figure 1.

*Figure 1: Percentage of UK electricity from coal since 1960*




**Source**: World Bank Data Viewer

The subsequent decline in coal generation has been rapid:

> May 2016 saw the first period without coal in the GB electricity mix,[1] lasting for over five hours.

> In a significant milestone, Great Britain saw its first 24-hour period without coal in April 2017.

> The current GB record for coal-free generation now stands at 76 hours.

> Total coal free hours have almost tripled each year since 2016, totaling over 1700 hours to date in 2018.

> Coal provided just 7% of UK electricity in 2017.

> The decline in coal use has coincided with Britain's renewable sector providing record amounts of electricity, with more than 7.4% coming from solar alone over the summer of 2018.

[a] This is very similar to the current level of coal generation in Chile.

The UK is now at the forefront of international efforts to find a pathway away from coal as a means of reducing $CO_2$ emissions and air pollution, including through its co-leadership of the Powering Past Coal Alliance (PPCA).

This paper seeks to contribute to this international momentum towards coal phase out through sharing insights on the UK's experience. It reviews the evolution of commercial drivers and policy incentives that have contributed to the decline of coal in the UK since 2000 and the delivery of the government's commitment to phase out coal use by 2025. It aims to provide insights that will be of relevance for policy makers and private sector actors alike.

Overall, we find that the decline in UK coal use resulted from a confluence of market drivers and regulatory interventions that have collectively eroded the position of coal in the electricity mix. These elements were not pre-planned but have resulted in coal phase out being recognised as a logical way forward.

Back in 2009 the government recognised that there could be 'no new coal without carbon capture and storage'. Despite efforts to promote Carbon Capture and Storage (CCS) technology it ultimately became evident that there would be no new coal in the UK, meaning that the existing but ageing power plants would not be replaced on a like-for-like basis.

In parallel, successive UK governments have acted to progressively increase the cost of $CO_2$ emissions. This has combined with stricter EU pollution controls to particularly impact the economics of coal generation. These policies have combined with a reduction in demand for electricity, the growth of renewables, and changes to the relative competitiveness of coal and gas in the electricity market.

The commitment in 2015 to phase out coal by 2025 recognised these shifts and sought to provide an orderly pathway towards retirement for coal power plants that would maintain security of supply while encouraging investment in alternative generation technologies.

In considering the strategies of power plant owners and operators in the UK, our analysis has found that coal plant conversion has been a minority strategy compared to the pursuit of plant closure and potential development of new generating capacity:

1. Their preferred option has been **continued operation** of existing coal power plants, until this becomes uneconomic due to market performance, age of components, and / or the need for significant upgrades to meet environmental regulations.
    - The timetables set for compliance with EU pollution control requirements have been essential in providing a pathway for decisions on investment or closure that applies to all generators. At each stage,

power plant operators have argued for looser standards and maximum flexibility.

2. In the majority of cases, coal power plants have then pursued **closure, with consideration of new developments on site**.

   > Over the past two decades, there has been a shift from consideration of investment in new large-scale coal power generation (and CCS), to Combined Gas Cycle Turbine (CCGT), and now towards specialised waste fuel units, small scale gas generation and also battery storage. This is particularly relevant as the value of providing flexibility to the power system increases compared to the provision of baseload power.

3. Only in a minority of cases have existing coal power plants opted for **conversion to operate existing power plant assets using alternative fuels.**

   > Biomass conversion has a mixed record, with technically successful conversions undertaken at Drax, but fires at Ironbridge and Tilbury.

   > Subsidies for biomass conversion are now no longer available and there are growing concerns over environmental and climate impacts, making further conversion projects unlikely after the conclusion of the Lynemouth project.

   > Conversion to waste pellets is now being proposed for the small power plant at Uskmouth, with claims that this could be a breakthrough technology for existing coal power plants.

   > Drax proposes to convert the last two coal units to provide the steam turbines of new CCGT units.

   > Alternative uses of existing power plant equipment are now being developed by technology providers (such as reuse of sites for thermal energy storage) and may yet be considered by the remaining UK power plants.

4. Over recent years, power plant operators have generally sought to **redeploy power plant staff to other roles** within the company (including management of site closure and demolition) and / or have offered retirement and retraining packages to workers.

Our analysis of the UK experience points to the central importance of government policy in providing a pathway for reductions in coal use and power plant retirement while enabling individual plant operators to decide on retirement decisions. Timetables for compliance with pollution control regulations have required a response from all power plant operators, while the introduction of effective carbon pricing has provided a market signal and boosted competition between fuels and technologies. The coal phase out commitment brings these elements together and provides clarity on the direction of travel, even ahead of legislation being introduced.

# 1. INTRODUCTION

This paper provides an overview of how coal power generation has changed in the UK over recent decades, charting its shift from the dominant source of electricity through to its phase out by 2025.

**Section 2** provides a brief history of electricity from coal in the UK, highlighting how it provided 97% of electricity generation in 1950, falling to just 7% of generation in 2017.

**Section 3** gives insights on the changing commercial and policy landscape of the past 20 years. We consider how electricity sector privatisation has interacted with the introduction of policies to drive reductions in air pollution and $CO_2$ emissions. This section identifies 'Push' and 'Pull' factors that have had an influence on utility company decisions.

**Section 4** then provides an overview graphic that considers what has happened to each of the UK coal power plants in operation since the year 2000. It identifies whether utility companies have decided to continue operations; close their coal power plants; or convert them to use alternative fuels.[2] We provide commentary on why decisions have been made at different moments in time, highlighting the importance of policy frameworks and timelines as a means of guiding investment and / or closure decisions.

**Section 5** considers the aggregate outcome of these individual decisions and how they have resulted in substantial declines in both capacity and generation in the period since 2012. We look at the impact this has had on overall UK $CO_2$ emissions and the evolution of the UK electricity mix.

**Section 6** provides conclusions on how utility companies have approached the question of coal plant closures, how this relates to the government commitment to coal phase out, and the importance of policy measures.

Our analysis has found that the conversion of coal plants to alternative fuels has been a relatively infrequent response from coal plant owners. There are however some notable exceptions that have pursued this route which we look at in more detail. **Annex 1** looks at the conversion of four units at Drax power plant to biomass, considering this as part of their broader corporate evolution. **Annex 2** provides an introduction to the conversions currently underway of the smaller coal power plants at Lynmouth and Uskmouth, to biomass and waste materials respectively.

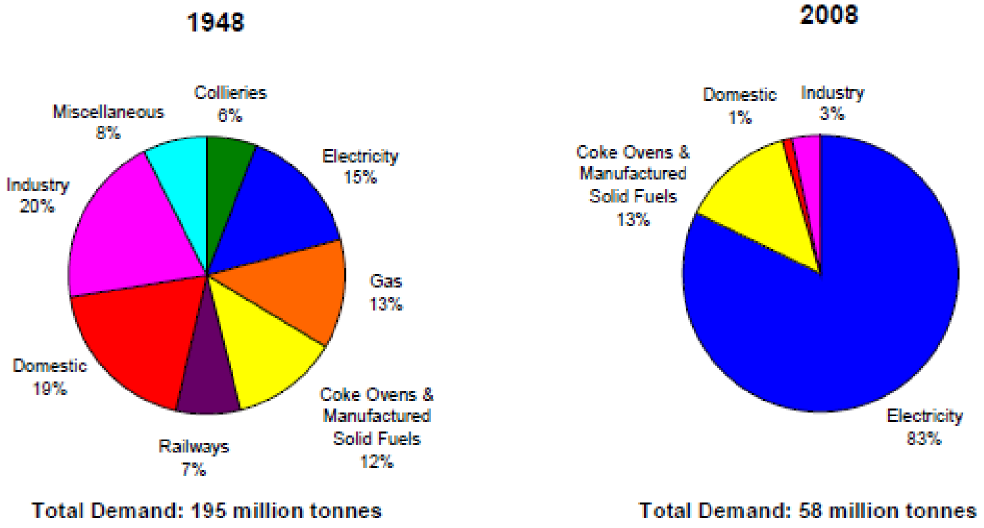
**Annex 3** provides details of all coal plants operating since the year 2000.

# 2. A BRIEF HISTORY OF ELECTRICITY FROM COAL IN THE UK

The United Kingdom (UK) was the cradle of the Industrial Revolution, with factories, railway transportation and street lighting all fuelled by coal. In 1882, the UK was the first country to use coal-fired electricity generation.[3]

By 1950, 97% of UK electricity generation came from coal, principally through small, locally-based power plants.[4] However these were only responsible for ~15% of total demand for coal, which was also used extensively by other industrial sectors. Over the subsequent 60 years coal use declined across all sectors except for electricity generation, as shown in Figure 2.

*Figure 2: Coal consumption by industrial sector 1948-2008*

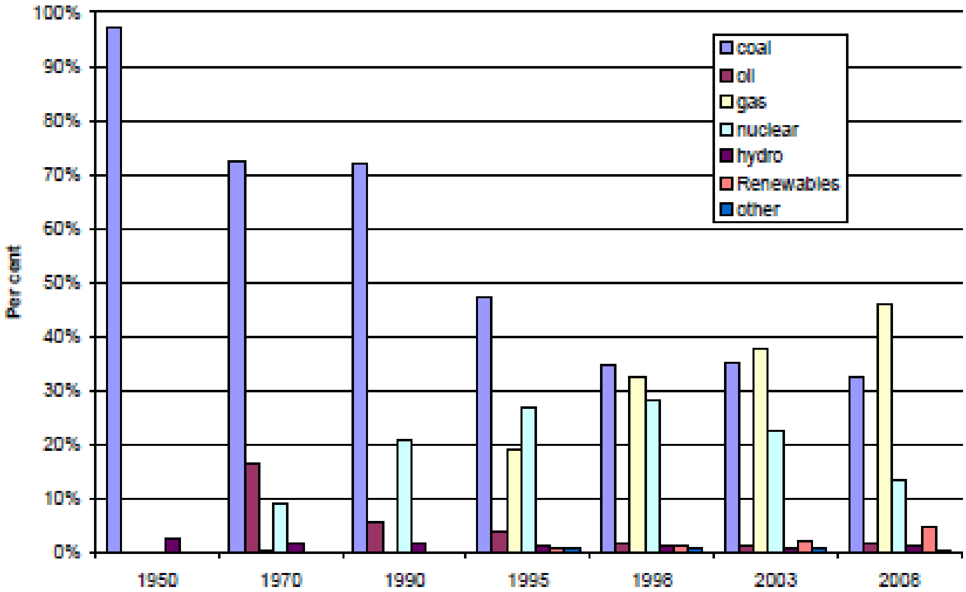



**Source**: DECC (2008) Digest of UK Energy Statistics (DUKES) 60th Anniversary paper

As of 1949 there were only two power plants larger than 500MW. Over the subsequent decades there was a transition towards larger power plants connected to the National Grid. This included construction of a fleet of large (2GW+) coal power plants in the late 1960s and early 1970s by the national Central Electricity Generating Board (CEGB). [5]

Coal continued to dominate UK electricity generation despite the introduction of nuclear power, which increased from 9% in 1970 to 21% of generation in 1990.[6] However, coal still provided 72% of electricity generation as of 1990, ahead of the 'dash for gas', which was enabled by the availability of gas supplies from the North Sea and the removal of a prohibition on gas use in electricity generation.[7] The first CCGT power plant entered operation in 1992, with gas generation rapidly growing to 19% by 1995 and to 32% by 1998, as shown in Figure 3.

*Figure 3: Electricity generation by fuel, 1950-2008*



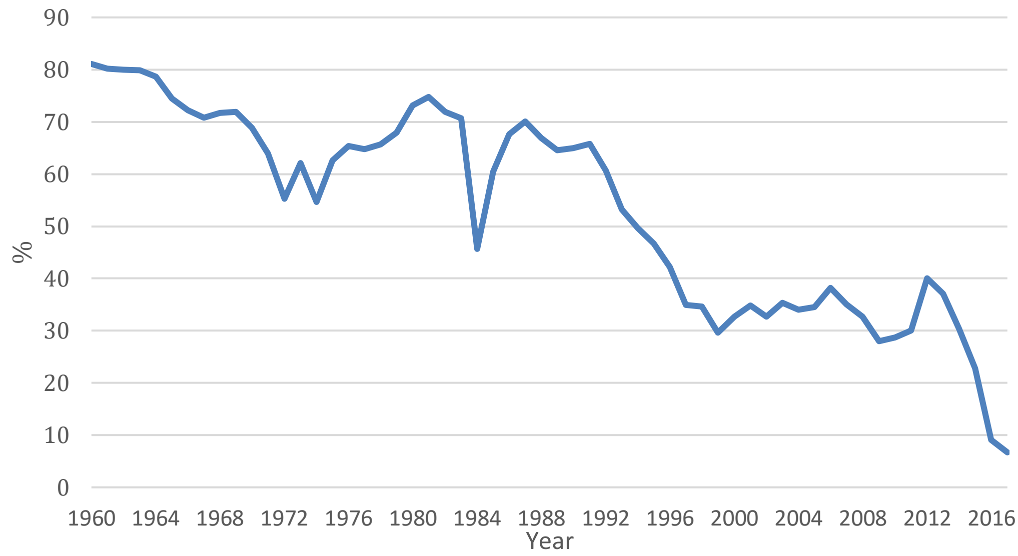

**Source**: DECC (2008) Digest of UK Energy Statistics (DUKES) 60th Anniversary paper

In 1999 gas use overtook coal generation for the first time. The following 15 years saw the market share of coal and gas vary depending on underlying fuel prices, with coal use typically providing 30 to 40% of generation.[8] We discuss these dynamics further in Section 3 in the context of the privatisation agenda and subsequent corporate strategies.

Over the past decade, the UK has become a leader in finding a pathway away from coal power generation, but this was not an inevitable outcome. As of 2008, the UK was facing a wave of new coal plant construction, which were proposed to replace ageing coal power plants. Ultimately, however, none of these were constructed – an outcome which we discuss further below.

Existing coal power plants continued to play a significant role in the power sector, and as recently as 2012 an upsurge in coal use saw 40% of UK electricity power generation come from coal, as shown in Figure 4.

*Figure 4: Percentage of UK electricity from coal since 1960*




**Source**: World Bank Data Viewer [9]

In November 2015, however, the UK government was the first to commit to a national coal phase out policy, which will see coal-fired electricity generation cease by 2025.[10] The subsequent decline in coal generation has been rapid:

> May 2016 saw the first period without coal in the GB electricity mix,[11] lasting for just over five hours, followed by a series of short coal-free periods.[12]

> In a significant milestone, Great Britain saw its first 24-hour period without coal in April 2017. [13]

> The current GB record for continuous coal-free generation now stands at 76 hours.[14]

> Total coal free hours have almost tripled each year since 2016, totaling over 1700 hours to date in 2018.[15]

> Coal provided just 7% of UK electricity in 2017.

> The decline in coal use has coincided with the UK's renewable sector providing record amounts of electricity, with more than 7.4% coming from solar alone over the summer of 2018.[16]

This paper provides context on this turn away from coal in the UK and the mix of commercial drivers and 'push' and 'pull' policy instruments that have made it possible.

# 3. THE CONTEXT FOR THE UK COAL-PHASE OUT: PRIVATISATION AND POLICIES

## 3.1. Market context

### 3.1.1 Pre-privatisation

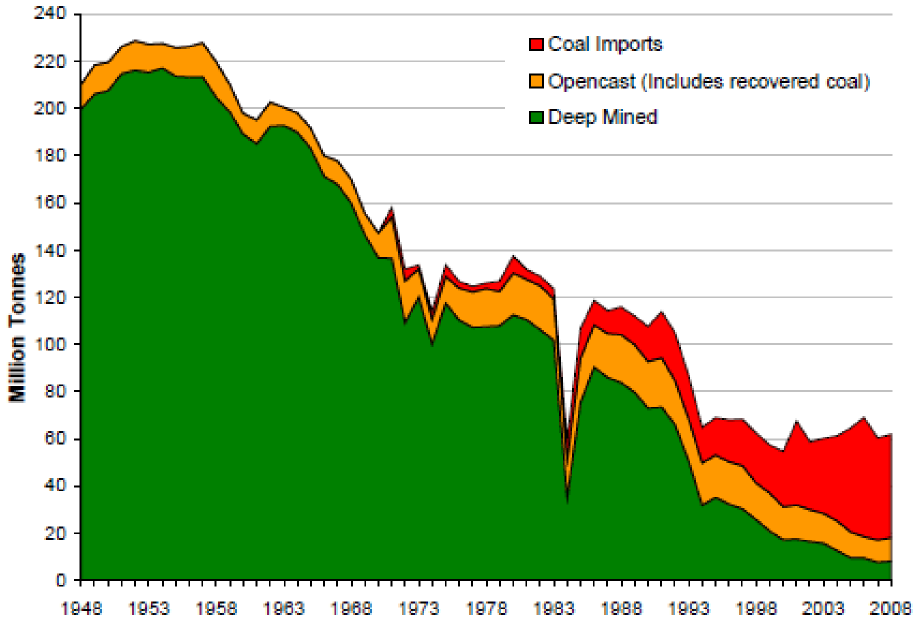
By the early 1980s, 71% of UK electricity supplies were still from coal-fired power stations, as shown in Figure 4**Error! Reference source not found.** above. However, this dependence had provided the coal mining unions with significant influence due to their ability to shut down the electricity system through industrial action – the impact of the miners' strikes of 1972 and 1974 is visible in Figure 4 **Error! Reference source not found.**and Figure 5 (as is the more substantial drop in coal production and use resulting from the subsequent strike of 1984).

As part of its broader economic policy reforms, the Conservative Government led by Margaret Thatcher was determined to counter this implied threat to security of electricity supply. Following a prolonged and acrimonious industrial dispute in 1984-5, the government implemented a programme of industrial reforms culminating in the privatisation of the UK's state-owned energy assets. This included the coal-mining sector and the entire electricity industry.

UK produced coal was considerably more expensive than that available on international markets. A central objective of the privatisation programme was to further shrink the UK coal sector to the point at which it was competitive with international supplies.[17] It was recognised that this would result in most UK mines closing and new fuel supplies would be required to maintain the necessary electricity generation capacity. In addition to encouraging investment in coal import facilities, the Government lifted a pre-existing ban on using natural gas as a feedstock for electricity generation, capitalising on the availability of oil and gas production in the North Sea.

UK domestic coal production peaked at the end of the 1950s, however imported coal only took on the largest share of coal use in the early 2000s, as shown in Figure 5.

*Figure 5: Coal Production and Imports 1948-2008*




**Source**: DUKES 60th Anniversary Statistics

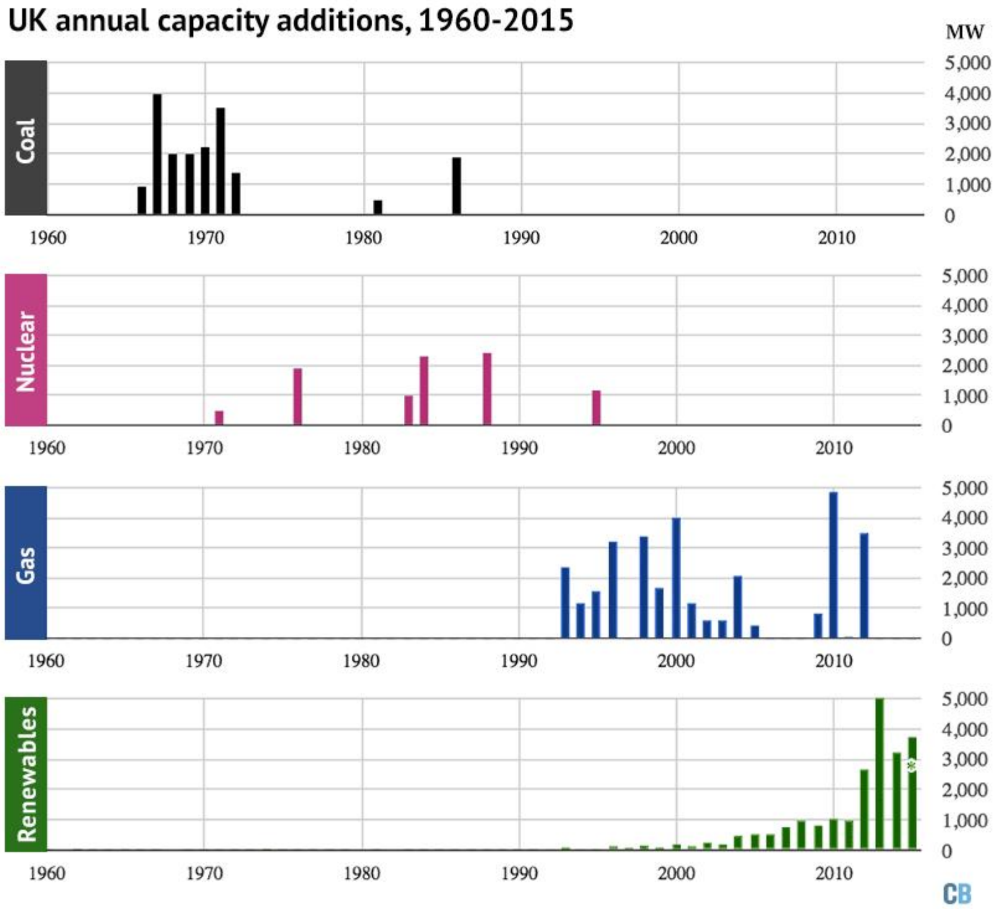
### 3.1.2 Post-privatisation years

Following privatisation, coal power plants were split between two new private companies – Powergen and National Power. Over the following two decades a series of corporate mergers, bankruptcies and acquisitions resulted in the emergence of a 'Big 6' of large, vertically-integrated utility companies combining generation with supply to wholesale and retail customers. Five of these six companies took on ownership of coal power plants as part of their generation portfolios. The similarities in portfolio structure among the major utility companies contributed to the emergence of convergent pricing strategies rather than aggressive price competition. A handful of coal plants were additionally owned by independent generators, most notably including Drax – the UK's largest and newest coal power plant.

Despite the politically controversial impulse towards privatisation and the subsequent reduction in size of the UK coal industry, the Government wanted to ensure that the decline was steady and well-managed rather than abrupt. Throughout the 1990s, a series of measures were put in place to support a planned programme of coal mine closures. In the period from 1990 to 1998, the Government brokered coal supply contracts between the UK coal producers and large power generators which secured a declining market share for UK coal and supported a planned programme of pit and power station closures.

One unintended consequence of these Government brokered contracts was that they effectively fixed market shares in the wholesale electricity market and this made it easy for the newly privatised large generation companies to sustain high wholesale power prices. Apart from arousing concern from the regulatory authorities, these high wholesale prices encouraged many new players to invest in CCGT power plants – the so-called ‘dash for gas’, as shown in Figure 6.

*Figure 6: UK annual capacity additions, 1960-2015*




**Source**: Carbon Brief 2015, Mapped: How the UK generates its electricity[18]

The combination of enforced power station divestment by the regulator and the growth of independent CCGTs resulted in a collapse in wholesale power price at the end of the decade. Indeed, once the Government-brokered coal supply contracts had expired in 1998 the new Labour Government introduced a temporary moratorium on new gas power stations to allow additional time for the UK coal mine closure programme to proceed.[19]

Figure 6 also highlights how the three most recent units at Drax had entered operation in 1986 alongside substantial investments in nuclear power during the 1980s ahead of the ‘dash for gas’ in the 1990s. The previous generation of coal power plants had all been constructed more than 15 years earlier. The major utility companies sought to ‘asset sweat’ these older power plants –

including by resisting requirements to retrofit pollution control equipment until it became necessary under EU law (which we discuss in Section 3.2. Emission regulation: air pollution and CO2).

By the year 2000 the majority of the UK's coal power plants had already achieved 30 years of operation. Their place in the UK market would depend on their ability to compete with existing and new-build CCGTs. Coal and gas jostled for position depending on underlying fuel prices, with both fuels taking between 30 and 40% of UK generation from the mid-1990s to the mid-2010s (see Figure 11).

As the UK's coal power plants had now become strategic assets for the emergent vertically-integrated electricity suppliers, the future of coal generation became a matter of corporate strategy and the maintenance of market share. With limited scope to win additional market share, companies embarked on strategies to maintain their relative position, which emphasised the importance of having a mixed portfolio to enable sufficient self-supply to retail customers.

### 3.1.3 The new decarbonisation agenda

A pivotal Government white paper was published in 2002 which acknowledged the challenge of climate change.[20] It added the decarbonisation imperative to those relating to security of supply and cost efficiency to create a new policy 'trilemma'. This established a new paradigm for the owners of coal-fired power plant since it became apparent that there was no long-term future for their assets unless $CO_2$ emissions could be progressively reduced. Critically, it was recognised that this would entail a programme of investments – both to improve the efficiency of the existing coal fleet and to replace this capacity with less carbon-intensive sources of power generation.

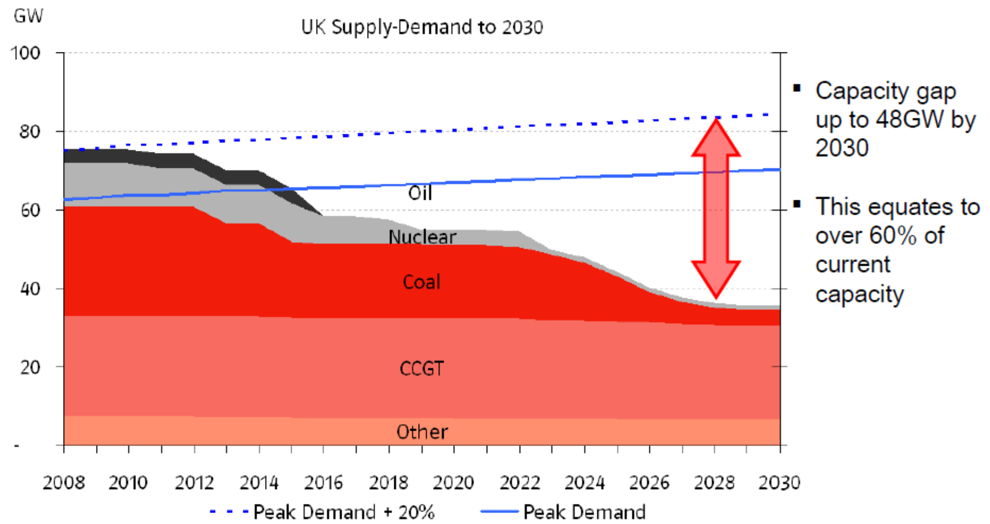
Initially, the Government supported a re-consolidation of the power sector in the hope that this would create companies that were sufficiently well-capitalised to provide the necessary investments. Six large vertically integrated companies were formed and four of these became part of even larger pan-European utilities. These companies sought to invest in power generation capacity such that it broadly matched the expected future customer demand.

The years from 2002 until 2009 saw a period of unusually high wholesale gas prices and this resulted in investments to prolong the life of existing coal plant being prioritised over further investments in CCGTs. This included moves to co-fire biomass in coal plant to take advantage of subsidy provided by the Renewable Obligation Scheme that had been introduced in 2002 (see Section 3.2.2 ). Subsequently, the rapid emergence of wind and solar power would challenge the operating regimes and profitability of both coal and gas generation – however this future was not anticipated as the 2000s drew to a close.

### 3.1.4 New coal to replace old coal?

In the mid-2000s the owners of the UK's remaining coal power plants faced the challenge of advancing plant age, relative inefficiency, and impending environmental regulations. This resulted in the major utility companies (and a number of independent project developers) embarking on similar strategies in which they intended to replace old coal power plants with new, more efficient, coal power plants as a means of maintaining a mixed generation portfolio. (In parallel, the government and nuclear power plant operator was similarly seeking to replace old nuclear power plants with new nuclear power plants).

*Figure 7: Utility expectations of demand growth and the 'need' for coal*




**Source**: Presentation to Confederation of British Industry Climate Summit, December 2008, Paul Golby, CEO of E.ON UK[21]

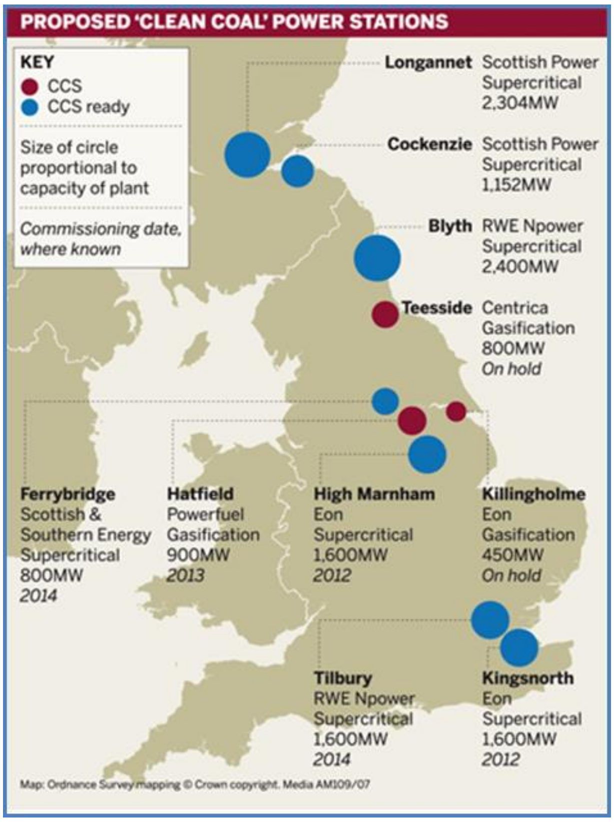
Figure 7 above presents a typical utility view of the time, which projected a future of rising demand and anticipated a 'capacity gap' which needed to be filled through investment in new generation. Given the recent rapid growth in gas generation, utility companies and government alike were keen to promote a new wave of coal plants as a means of maintaining energy security through diversity.

Despite the recognition that actions to address climate change would ultimately require a reduction in $CO_2$ emissions, utility companies (erroneously) took the view that increased efficiency of generation would be a sufficient first step – in part due to similar investments being undertaken by their European parent companies elsewhere (especially in Germany). Little attention was paid to the overall lifetime emissions of any new power plants.

As of January 2008, over 13.5GW of proposals for new coal power plants were under development, as shown in Figure 8 below.

In parallel, however, 2008 saw the passage of the UK's Climate Change Act which provided the basis for formal advice to government from the new Committee on Climate Change (CCC) and the introduction of multi-year carbon budgets.[22] The Committee immediately advised that any new coal plants would need to retrofit and operate CCS technology from the early 2020s, as lifetime emissions from new coal power plants would be incompatible with carbon budgets.[23] This further strengthened the growing civil society campaign against new coal power plants and heightened the importance of the UK government's CCS competition that had been launched in 2007.[24]

*Figure 8: Proposed 'clean coal' power stations, January 2008*

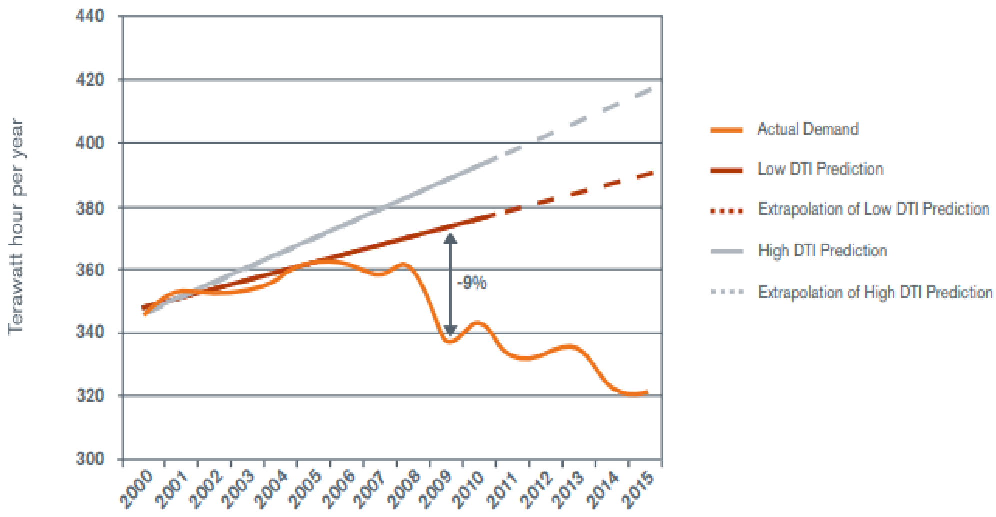



**Source**: King coal promises to clean up, ***ENDS Report 396, January 2008***

In 2009, the then Labour government subsequently announced a policy of 'no new coal without CCS'[25] and committed additional funding, including financial support for engineering studies being undertaken by the remaining two bidding projects.[26]

Ultimately, no new coal power plants were built. The proposal by E.ON to build a new high-efficiency coal plant at Kingsnorth (including a CCS demonstration unit) attracted further significant public opposition; the new Coalition Government was unwilling to commit additional capital funding to demonstrate CCS technology at scale following the financial crash and 2010 election; and increasingly difficult market and regulatory conditions reduced the appetite of the energy companies to make significant merchant investments in power plant. Importantly, demand for electricity fell following the financial crisis – but then continued to fall thanks to the impact of increased energy efficiency policies, significantly reducing the need for new capacity, as shown in Figure 9.

*Figure 9: Forecasts of electricity demand compared with actual demand*




* UK Demand predictions are from the DTI Energy Paper 68. Forecasts from 2010 onwards are an extrapolation of the trend presented from 2000 – 2010. Demand is transmission level demand and has been updated using DUKES data.

**Source:** Ofgem 2016 'Future Insight' series

### 3.1.5 Market signals needed

In parallel, political concerns over the level of retail energy prices in the UK, and the reduction in profit margins for utilities across Europe resulting from increasing levels of competition, led the Government to conclude that it was not appropriate to rely on the balance sheets of large energy companies to deliver the necessary investments in low-carbon generation. Instead, it was decided to introduce a new set of trading arrangements designed to steer investment decisions and deliver Government policy. 'Electricity Market Reform' (EMR) was initiated following the 2010 general election, bringing together incentives for low-carbon generation with increased carbon pricing for existing power plants. We discuss this in Section 3.2. Emission regulation: air pollution and CO2

Increasingly tough regulation of retail electricity prices has undermined the logic for vertically integrated business models and there is now no prospect that the costs of generation investments can be passed through to customers if they are not cost-competitive with other generation sources.[27] In consequence, it has become difficult to justify any major investment in generation without some form of longer term regulated income stream. Any investment which does not benefit from regulated income support must deliver a return very quickly, reflecting the perception of uncertainty amongst investors.

This situation has left the Government with a strong direct influence over key investment decisions facing existing and prospective owners of generation capacity. This includes the choice facing owners of coal plant to invest to extend lifetime, convert to alternative fuel or to close.

### 3.1.6 Push and Pull – utility strategies and coal plant lifetimes

In the first years of the 2000s a handful of coal plants were retired, removing generating capacity and thereby maintaining higher market prices. Subsequently, however, the convergent competitive strategies of the utility companies saw them seek to maintain coal power plants in operation as part of their generating portfolios up until the point that significant investments were required (due to plant age resulting in technological failures) or imposed (as a result of environmental regulation to reduce air pollution) – which we discuss below.

Some of major utility companies believed that they had a competitive advantage in their ability to construct and operate coal power plants. This combined with the 'competitive' inertia of the wholesale market and saw utilities seek to maintain coal generation in the mix. This pathway was diverted through the combination of civil society pressure, the fall in overall demand for electricity, and the introduction of a price on $CO_2$ emissions.

Overall, the commercial strategies of the major utility companies were principally centred on 'not losing' through maintenance of a portfolio of generating options, resulting in similar parallel approaches that sought to maintain coal plants in operation. Conversely, it was generally the case that independent generators took a more enterprising approach to the future of coal power plants – as we discuss in the case studies on plant conversions below.

## 3.2. Emission regulation: air pollution and $CO_2$

### 3.2.1 Acid rain

During the 1980s and 1990s, the key pollution concern for coal-fired power plants involved the emissions of nitrous oxides ($NO_x$) and sulphurous oxides ($SO_x$) – the latter gases being responsible for acidified rainfall in neighbouring countries, especially Scandinavia.

The environmental regulators developed a programme of continually updated emissions standards based on the 'BATNEEC principle' (Best Available Technology Not Entailing Excessive Cost). This involved a negotiation process between regulators and power generation companies to identify the investment that could be justified based on future requirement for coal generation. Throughout the 1990s, this process was closely aligned with the Government brokered coal contracts and the associated pit and power station closure programme. The costs of implementing Flue Gas Desulphurisation (FGD) were integrated into the privatisation process, but subsequently not fully delivered (but without any recovery of monies to the public purse).[28]

As a consequence, Drax and Ratcliffe power stations were fitted with FGD scrubbing technology to target the sources of acid rain. However only 6GW of FGD was fitted overall, compared with the 12GW originally intended. Other power plants opted to change operational practices (e.g. fuel source) to reduce emissions, while some were closed. The reduction in consumption of high-sulphur domestic coal and growth of both imported coal and gas generation both helped to reduce emissions without requiring pollution controls. Reviews of the UK regulatory experience have pointed to the inclusion of multiple flexibilities that assisted plant operators rather than prioritising environmental outcomes.[29] This delayed investment in FGD, resulting in a subsequent rush to compliance later in the 2000s.

### 3.2.2 Large Combustion Plants Directive and Industrial Emissions Directive

The next iteration of the regulatory approach subsequently resulted in the closure of significant coal power capacity in the period 2010-15 following the application of progressively tighter pollution standards to all coal power plants from 2008 onwards.

As part of the process to align environmental standards across the EU, national approaches to regulating non-carbon emissions were harmonised within a single piece of EU legislation – the Large Combustion Plants Directive (LCPD) – which was introduced in 2001. This legislation continued the process of incremental improvements in environmental standards through a series of upgrades. The final set of plant standards defined by the LCPD had to be implemented before 2015 and, by this stage, effectively required all plants that intended to operate after 2015 to fit FGD or equivalent technology. Given the lead times necessary to plan and install the upgrades, power station owners had to commit to comply with these new standards before the impact of the 2008-09 economic recession on gas prices had become apparent, and before the Government’s decision to introduce the Carbon Price Support (CPS) mechanism was taken. Despite 8GW of coal plant deciding to close in the period between 2012 and 2015 because of the new standards, 19GW of capacity was upgraded and remained in operation at the end of 2015.

In 2016, the LCPD was incorporated into the Industrial Emissions Directive (IED) and this change was associated with a further tightening of the emissions standards that would require compliance by 2020. Table 1 provides details on the respective Emissions Limit Values required under the different waves of regulation for coal power plants that had commenced operations prior to 1987. Stricter emissions standards were also introduced for new power plants. Most recently, standards for Mercury abatement have been introduced in the BREF process, applicable from 2021.

The reductions required in $NO_x$ emissions under the IED were particularly significant to the degree that early CCGTs were also not compliant and facing decisions as to whether they should be upgraded or closed. Only two coal power stations (Drax and Ratcliffe) were compliant (or able to comply at low cost) with the IED standards and Drax had already made the strategic decision to move away from coal (see Annex 1. Case study: Large Coal Plant Conversion: Drax).

*Table 1: Emission levels applicable to hard coal power plants > 300 MW thermal*[30]

| | **All units are in mg per cubic meter of flue gas except for mercury (microgram)** | | | |
|---|---|---|---|---|
| | **Before 2016 (2001 LCPD)** | **2016 IED limits** | **2021 BREF limits** | **Best Available Techniques (BAT)** |
| **$SO_2$** | **400**<br>• Or $DeSO_2$ rate > 94%<br>• Or 'peak load derogation' up to 800 | **200**<br>• Or DeS02 rate > 96%<br>• Or 'peak load derogation' up to 800 | **130**<br>• Or for L DeSO2 rate > 97% and max 320 (existing FGD)<br>• Or > 99% DeSO2 rate and max 200 (new FGD)<br>• Or 'peak load derogation' up to 220 | **10**<br>• (when using low sulphur coal with wet FGD) |
| **$NO_x$** | **500**<br>• Or 'peak load derogation' up to 600<br>• For solid fuel of low volatile up to 1200 | **200**<br>• Or 'peak load derogation' up to 450 | **150**<br>• Or 'peak load derogation' up to 340 | **65** |
| **Dust** | **50**<br>• Up to 100 in case of old plants burning unfavourable sold fuels | **20**<br>- | **8**<br>• Or 'peak load derogation' up to 14 | **2**<br>- |
| **Mercury** | - | - | **4µg HC** | **<1µg** |
| **Net electrical efficiency**<br><br>**Net total fuel utilisation (CHP)** | • None | • Optional due to ETS | • 45-46% ("new" units)<br>• 75-97% | • 45-46% ("new" units)<br>• 75-97% |

**Source**: Updated from Sandbag et al (2016) Lifting Europe's dark cloud

**Note:** FGD= Flue Gas Desulphurisation; $DeSO_2$ = desulphurisation rate; peak load = operated less than 1,500 hours/year.

Whilst some of the other coal power stations did initially retain the option to upgrade their plant, the combination of low demand, low gas prices and the CPS soon made it clear that there would be no business case to make the necessary investments without additional financial support. There was some expectation that the capacity mechanism (which was introduced as part of the EMR) would provide the necessary additional income. This did not occur, however, as capacity margins have remained healthy; the capacity price has remained correspondingly low; and stricter efficiency standards were introduced to ensure that old power plants could not secure 15-year contracts off the back of investments in pollution control systems required by law.[31]

As we discuss further below, the UK Government decided in the run-up to the UNFCCC Paris climate conference at the end of 2015 to announce an end-date for unabated (i.e. where $CO_2$ emission can enter the atmosphere) coal-fired power generation in 2025.[32] This important statement reinforced the decision of the bulk of the UK coal fleet not to invest to upgrade their plant by 2020, but to instead maximise operating lifetimes according to success in the capacity market, if necessary, by taking a derogation to only operate as peaking plant.

### 3.2.3 Emissions trading for $CO_2$ reduction

Whilst the concept of allocating tradable permits to emit within a reducing overall cap had been applied to tackle acid rain in the US power system, the approach had not been adopted in the UK. However, as the need to reduce emissions of $CO_2$ became apparent at the turn of the century, emissions trading was selected as the preferred regulatory mechanism for addressing greenhouse gases in the power sector. Regulators would focus on establishing the appropriate cap to apply to overall emissions, leaving generation companies full flexibility in how to deliver the necessary reductions at least cost. Moreover, emissions permits could be allocated to generation companies without charge based on expected generation requirement. This mirrored the philosophy underpinning the BATNEEC negotiations since it enabled generators to invest to meet planned generation requirements.

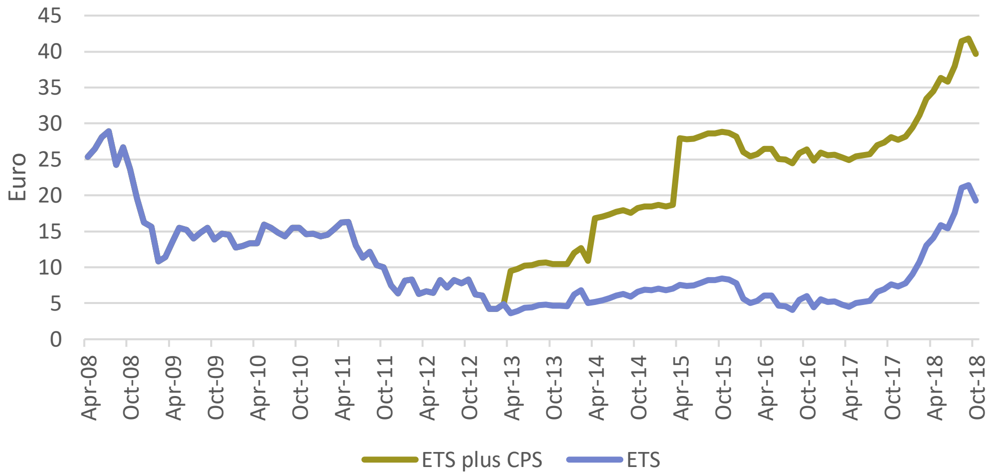
Emissions trading was initially trialled at a UK-level between 2002 and 2005 ahead of the introduction of the EU Emissions Trading System (EU ETS) in 2005. This has involved three phases of development (2005-2007, 2008-2012, 2013-2019). Free allocation of permits to power generators was allowed during the first two of these phases.

The cost of carbon emissions rises with the scarcity of the tradable permits and therefore depends on the level of the overall cap. European policy makers have tended to adopt a cautious approach to setting this cap and did not foresee the impact of the 2008-2009 economic recession on electricity demand.

As a result, EU ETS prices remained low (as shown in Figure 10) and did not have a significant influence on the relative economics of coal and gas-fired power generation. More recently, the EU has introduced measures to tackle the over-allocation of permits and prices have begun to rise ahead of the fourth phase of the scheme which is due to start in 2020.

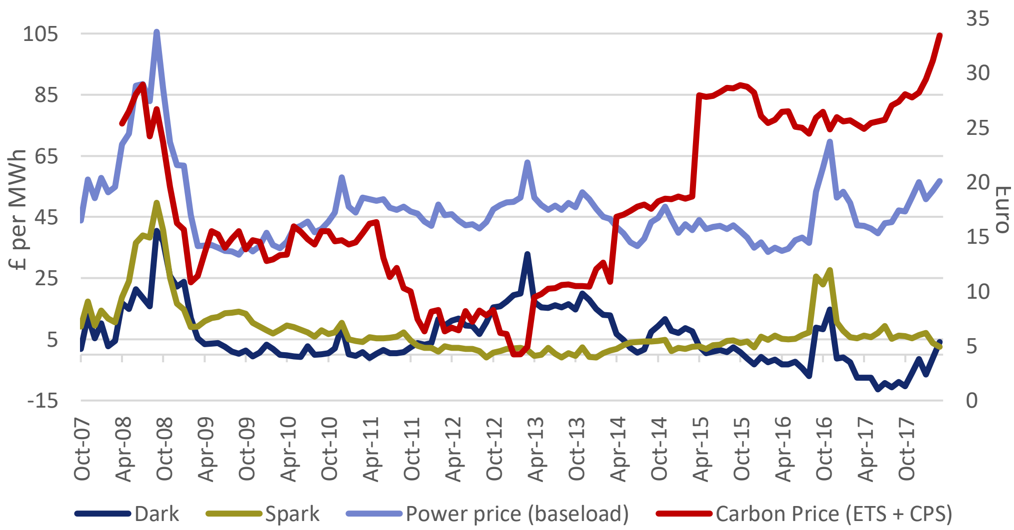
The low level of the EU carbon price was a key factor behind the introduction of the UK CPS in 2013 as part of the EMR agenda. This policy introduced a tax on fossil fuels used for power generation and was designed to replicate the impact of a carbon price that did not fall below a pre-specified level. Whilst the floor price has not escalated as high as originally envisaged, it has created a significant additional cost for fossil-fuelled power generators, particularly coal. The combined cost of carbon of the EU ETS and UK CPS is shown in Figure 10.

*Figure 10: UK carbon pricing: EU ETS price plus UK Carbon Price Support from 2013*




**Source**: Various Sandbag sources

*Figure 11: Comparison of coal and gas generation costs 2007 to present (£ per MW)*




**Source**: Ofgem 2018

This, in turn, has had a significant impact on the relative economics of coal and gas-fired power plant such that now, given current fuel costs, gas-fired generation is significantly cheaper than coal-fired. Figure 11 illustrates how the increase in carbon price (red – right axis) has resulted in profit margins for gas generation ('spark' / gold) overtaking those for coal ('Dark' / dark blue). Notably, this change in generation profile and increased carbon costs has only had a marginal impact on overall power prices (light blue) which are influenced more strongly by other factors beyond marginal changes to carbon prices. In the UK, CCGTs set the market price which subsequently tracks underlying wholesale gas prices.

### 3.2.4 Electricity Market Reform and low carbon support mechanisms

The new regime for electricity trading was developed during the period from 2008-2012 and introduced in 2013. It included measures that were intended to progressively restrict use of high carbon emitting plant (CPS and emissions performance standards) and measures to support investment in lower carbon generating capacity (feed-in-tariffs and a capacity mechanism).

This combination of measures sought to ensure that the UK would be able to decarbonise the power sector without compromising security of supply. Ultimately, continuing concerns in the early 2010s about the implications for energy costs and security of supply meant that a weak form of the emissions performance standard was adopted (so that it initially only applied to any new coal power plants that might be constructed with CCS), and the CPS has not escalated as originally intended,[33] remaining frozen at £18/tonne.

In parallel, the UK Government introduced a series of measures to encourage investment in low carbon technologies across the categories of renewables, nuclear and CCS. This has resulted in the consideration, pilot, and subsequent commercial decisions to invest (or not) in emissions reduction projects at coal power stations. Two high level 'low carbon' incentives were made available. Firstly, operators could initially co-fire biomass with coal, latterly becoming an incentive for full conversion to burning biomass rather than coal. The second pathway was to install CCS technology to remove $CO_2$ either before or after fuel combustion. Box 1 and Box 2 look at these options in more detail below.

### 3.2.5 Announcing the UK coal phase out

Ahead of the 2015 general election, each of the leaders of the three main political parties signed a commitment to maintaining UK leadership on climate change, which included identification of the need for further decarbonisation of the UK electricity sector and a reference to the particular role of coal.[34]

Subsequently, the new Conservative government embarked on a series of changes to energy policy. In November 2015, the then Secretary of State for Energy and Climate Change Amber Rudd made a major speech regarding the government's energy priorities and announced that the UK would commit to concluding a phase out of unabated[35] coal generation by 2025.[36] This commitment has subsequently been consulted upon[37] and reaffirmed following the 2017 general election, with policy details and proposed legislation published in January 2018.[38]

The announcement of the UK's coal phase out policy commitment reflected the continued shift in thinking away from the assumption that old coal would be replaced with new coal. Both government and industry recognised that there would be no investment in CCS on coal power generation, meaning that there was only now a pathway to closure for the UK's remaining coal power plants. While utility companies continue to be focused on maximising the economic return from their power plants ahead of retirement, the government recognised that there was a need to anticipate closure dates and enable a smooth investment pathway for replacement capacity from cleaner sources of electricity generation. As a consequence, the coal phase out policy presented itself as a means of providing domestic visibility on the scale of the investment opportunity and a positive international signal of commitment to action on climate change.

### 3.2.6 Push and Pull – pollution controls and economic incentives

The introduction of pollution control regulations and carbon pricing have both served as push factors motivating a reduction in generation from coal power plants and / or the closure of non-compliant and ageing units. The government's commitment to the phase out of coal by 2025 also serves this role by providing clarity on the forward market context.

In contrast, the availability of capacity market payments has provided a pull factor that has encouraged some power plants to continue operations for longer prior to closure (without resulting in significant upgrades to pollution controls that would allow for continued operations beyond 2020). Similarly, the availability of subsidies for biomass co-firing and conversion has been a pull factor that has resulted in substantial capacity switching to biomass fuel stocks. The previous availability of CCS incentives through two competition processes were insufficient to secure investment in CCS.

Overall, these regulatory interventions and market (dis-)incentives have been necessary to cut through the instincts of utility companies that would otherwise have sought to continue the operation of coal power plants for as long as possible without needing to make substantial investments. While the advancing age of the UK's coal power plants would have resulted in an eventual phase out, experience over recent decades had shown that this would not have been on a timescale aligned with the UK's climate change commitments and carbon budgets.

*Box 1: Biomass subsidies and plant conversions*

The Renewables Obligation (RO) mechanism was first introduced in 2002 to encourage investment in renewable technology. This applied to co-firing coal with biomass or converting completely to biomass fueling. Energy suppliers were required to buy a certain proportion of 'renewable' electricity and this could, therefore, command a higher price.

The RO was replaced (after a period of parallel operation) by the feed-in-tariff (FiT) mechanism introduced as part of the EMR in 2013. FiT subsidy was not made available for biomass cofiring, but early FiT contracts were granted for biomass conversion at Drax and Lynemouth. No funds have since been set aside to support biomass power plants in the future (either conversion or new-build), with Drax converting its fourth unit at lower cost underneath a cap on subsidy support. Existing biomass subsidies are scheduled to end in 2027. Drax CEO Will Gardiner has highlighted that they aim to reduce the costs of biomass generation down from the current ~£75/MWh to ~£50/MWh by that date.[39]

The initial co-firing of biomass at several power plants provided some short-term revenue support to coal plant operators but was ultimately a road to nowhere as it did not offer a means of extending the operational life of the plant. The early operational experience of biomass was also poor, with both Tilbury and Ironbridge experience significant fires due to the volatility of biomass material.

Full conversion to biomass offered the prospect of an increased operational timeframe, particularly as a result of biomass being 'zero-rated' for $CO_2$ – thereby providing a competitive benefit that helped offset the increased fuel costs.

Over recent years, however, there have been increasingly active civil society campaigns against the use of biomass due to concerns regarding the negative environmental impact of woodchip production,[40] the real climate impact of unabated biomass burning,[41] and the high financial cost of biomass subsidies compared to those given to other renewable technologies.[42]

The CCC has very recently acknowledged these concerns, publishing a report in November 2018 assessing the UK's biomass use.[43] It states that the use of biomass needs stricter governance and should cease at the end of existing subsidy contracts, unless power plants include CCS. The CCC recommends that only the most beneficial use of biomass should be prioritised: namely to lock away $CO_2$ via 'negative emissions'.

# 4. OVERVIEW OF UK COAL POWER PLANTS AND CONVERSION / CLOSURE DECISIONS.

In this section we provide a timeline graphic and accompanying table providing details of all the UK coal plants in operation since the year 2000. Drawing on resources in the public domain, we have compiled an overview of the principal options taken by power plant operators.

Figure 13 provides an overview of the 21 coal power plants in operation since the year 2000, identifying each of the 76 generation units. This identifies the timings of major investment decisions and technology upgrades (or lack of) that have contributed to their continued operation and /or retirement. Figure 12 provides a Key and explainer of symbols used.

*Figure 12: Key for Figure 13 on following page*

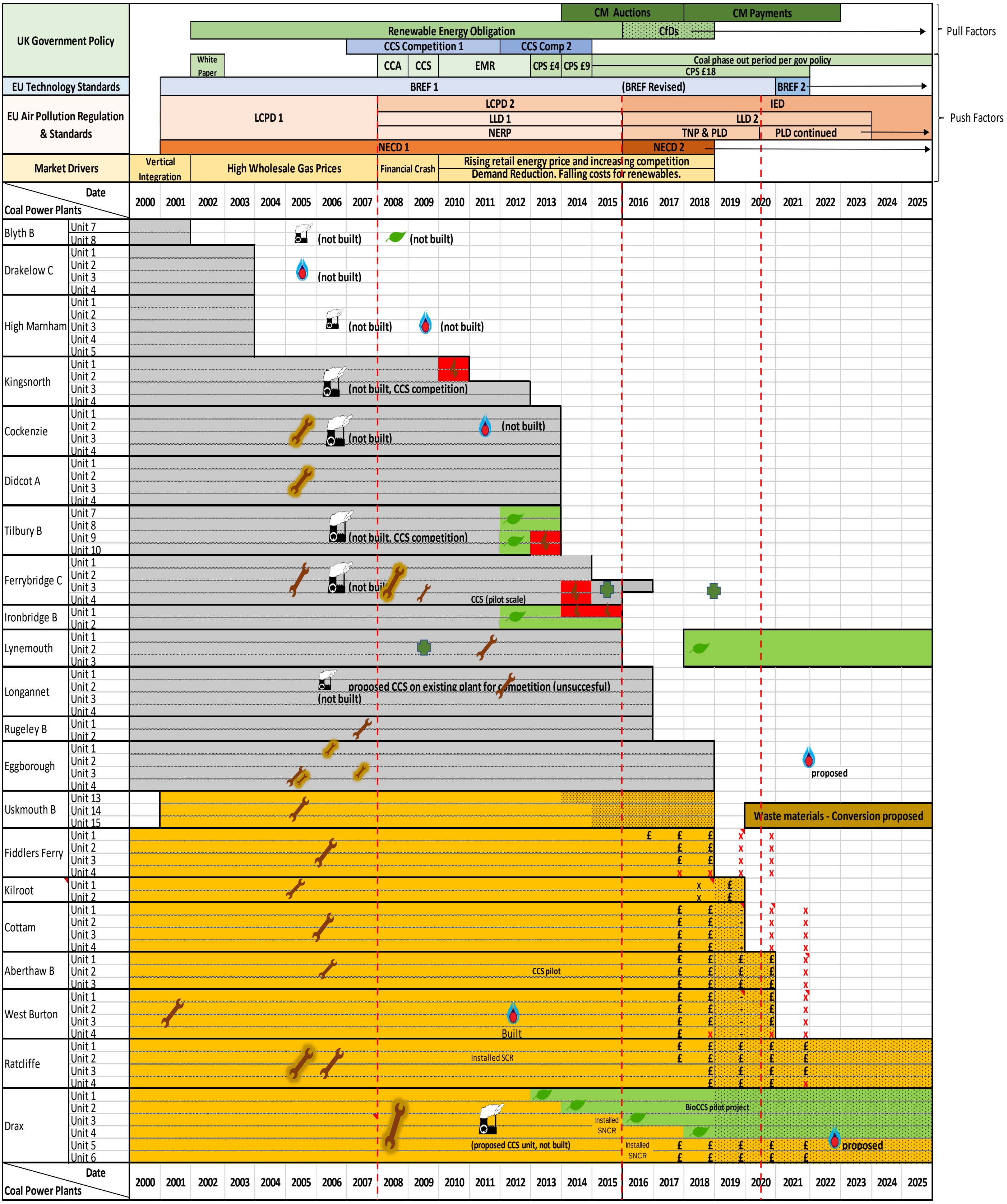
| | |
|---|---|
| (grey) | Closed |
| (yellow) | In operation |
| (dotted yellow) | Tentative |
| Arrows | Ongoing |
| (leaf, green) | Biomass conversion |
| (brown) | Waste conversion |
| (fire, red) | Power plant fire |
| (green cross) | Alternative fuel unit on site |
| (highlighted wrench) | Boosted overfire air technology fitted |
| (wrench) | Flue-gas desulphurisation technology fitted |
| (factory) | New coal plant proposed (Note that none were built) |
| **CCS** | CCS project proposed |
| **£** | Capacity market contract secured |
| x | Capacity market contract not secured |
| - | Currently without capacity market contract, may bid again |
| (gas drop) | Gas plant proposed |

**Source**: E3G Analysis

Figure 13 also identifies the relevant timeframes for specific elements of the push and pull factors discussed in Section 3. This enables consideration of how their associated timeframes have contributed to operator decisions regarding coal plant retirements, upgrades, and replacement. We discuss these dynamics here below.

The table in Annex 3 complements Figure 13 by providing greater detail on decisions made for each coal plant on whether to upgrade or pursue a pathway to retirement. It also tracks changes in ownership, highlighting how operation of a physical power station asset can continue uninterrupted across changes in corporate strategy or commercial structures.

## Figure 13: Overview of UK coal power plants since 2000




**Source:** E3G Analysis

## Closures dominate, conversions in the minority

In the year 2000, the UK had 21 coal power plants in operation, comprised of 76 generating units and totaling 33GW installed capacity. Figure 13 and Table 2 jointly provide an overview of the evolution of the UK coal fleet since then. We firstly set out headline details regarding the closures, conversions and continued operation of power plants during this period. We then comment on the drivers behind these decisions and the implications going forward.

### 13 power plants closed

As of October 2018, 13 of these coal power plants have fully closed plus four units at Drax have converted to burn biomass. This means that a total of 50 units totaling 21GW installed capacity have ceased coal generation. This has resulted in a reduction of 61% in the number of power plants, and 64% in the number of units and level of installed coal capacity, compared with the year 2000.

These 13 closed coal power plants have considered and / or implemented a range of strategies:

- seven considered construction of a new coal plant on site (at least two of which would have integrated some element of CCS), but none were built.
- three considered construction of a new gas plant on site, but none were built.
- two trialled biomass conversion (Ironbridge and Tilbury) but experienced substantial fires and subsequently ceased operations and closed the plant.
- one considered the retrofit of CCS to the existing power plant (Longannet), but the project was not taken forward following a decision by the UK government that it would not provide financial support.
- one has constructed a smaller alternative (waste) fuel plant on site (Ferrybridge), which now plans to construct a second unit.
- one is currently close to completing a conversion to biomass (Lynmouth). See Section 7 for further details.
- one is seeking to secure a capacity market contract that would enable it to build a new CCGT on site (Eggborough).

### Eight power plants still operational

As of October 2018, the UK still has 8 coal power plants with some form of operation continuing. These plants contain 26 units, totalling 12GW of installed capacity. Among these plants:

- one has successfully constructed a CCGT plant on site (West Burton).
- one has closed and reopened several times (Uskmouth) and is now proposing to convert to burning waste pellets. See Section 7 below.
- one proposed to construct a dedicated new coal CCS unit on site (Drax) but the project was cancelled. It is instead now proposing to convert the last two remaining coal units to become CCGTs, alongside investment in battery storage. See Section 6 below.

Beyond Drax and Uskmouth, none of these remaining plants have announced any firm plans for future development or conversion. We understand that internal planning is however now underway and options are being considered.

## Three waves of closures

In considering the timings and interactions of the Push and Pull drivers noted in Figure 12, we are able to identify three waves of coal plant closures since 2000.

### Wave 1 – early 2000s

Three coal plants closed in the period 2001-03. These closures were primarily for commercial reasons, reflecting the relative age of the power plants and a broader strategic aim of maintaining a high wholesale cost of electricity in the period following privatisation. The closures also followed a period of churn in the industry with subsequent efforts to reduce costs and manage generation portfolios.

### Wave 2 – 2010-15

Seven coal plants closed during this period (plus Uskmouth, which subsequently reopened under different ownership). The primary driver for most of these closures was the decision to take the Limited Life Derogation (LLD) (of maximum 20,000 hours operation) rather than upgrading to meet the pollution standards required under the second period of the LCPD.

Conversely, the 2008 deadline for compliance with the LCPD standards was successful in forcing power plant operators to install pollution controls, with the majority of plants operational at the time opting to do so. This resulted in a 'rush to retrofit' prior to 2008, visible in Figure 12.

### Wave 3 – 2015-2018+

In the current wave of closures, three power plants have closed so far due to the combination of worsening plant economics and impending retrofit costs under the new IED if they were to continue operations. Eggborough had opted to take the LLD option but used very few of the 17,500 hours available to it before closing in 2018. Longannet and Rugeley had options for continued operation under the Transitional National Plan (TNP), but faced economic losses and closed in 2016. Market analysis from the time highlighted the combination of falling power prices and increasing carbon costs radically reducing earnings for coal power plants.[44]

Similarly, two coal power plants (Eggborough and Fiddlers Ferry) had announced closure in 2016 but then temporarily continued operations following receipt of additional contracts for capacity and ancillary services.[45] Eggborough has subsequently closed, while Fiddlers Ferry is the next plant most likely to close after the conclusion of its capacity contract in 2019.

Kilroot power plant in Northern Ireland failed to secure a capacity contract in the Irish electricity market auction in early 2018. Plant owner AES announced that it was likely to close, but this has now been postponed for at least a further 12 months following an exchange of capacity contracts.[46]

Notably, plant operators have sought to keep their options open under the IED by taking the TNP route rather than committing to closure under the LLD. This reflects the potential receipt of capacity market payments and the option of taking the Peak Load Derogation (PLD) (of <1500 hours a year) as a means of extending operational life.

Looking ahead, only Ratcliffe and Drax are likely to be able to comply with IED limits from 2020, and even these plants may need to make further upgrades to meet the new Best Available Technology Reference (BREF) standards in 2021. All of the other power plants would need to install pollution controls, close completely, or take the PLD route by 2020.

These decisions on continued operation or closure are now dependent on the relative success or failure of power plants in capacity market auctions – particularly in light of the collapse of wholesale revenues and reduced load factors. Figure 12 indicates potential closure dates based on current capacity contracts.[47]

### Push stronger than Pull

Across each of these waves of closures, there has been a stronger Push impulse towards closure, with relatively weaker Pull factors encouraging coal plant conversion. Indeed, the preference of plant operators has been to build a new facility (whether coal, gas or alternative fuels) rather than undertake conversion of the existing power plant. This reflects the engineering and technical challenges of converting relatively older and less efficient UK power plants.

### Box 2: CCS experience

During 2005 the UK held the Presidency of both the EU and the G8. As part of its leadership on climate change it advocated for international efforts to demonstrate CCS technology, particularly for coal plants given the rapid growth in coal use in China and the proposals for a wave of new coal plants in the UK, Germany, USA and elsewhere. The UK government subsequently developed two CCS competition processes to bring the technology to commercial scale.

Over the past decade there have been at least 10 commercial scale proposals for coal CCS projects (including one retrofit project at Longannet, plus one gas project at Peterhead), but none have entered construction after the government decided not to provide capital funding support. Detailed engineering designs and cost data from the competition projects are available online.[48]

At least four of the UK's existing coal power plants have undertaken pilot scale testing of $CO_2$ capture technologies, which Drax will also undertake for biomass combustion. There are no prospects for retrofit of CCS to remaining coal plants given their age and relative inefficiency. In 2017, the last remaining proposal for a new coal CCS project (Caledonia) announced that it would use gas as a feedstock rather than coal if it were to proceed into construction.

The UK regulatory framework allows for new coal power plants to be constructed if CCS technology is integrated and operated to effectively reduce $CO_2$ emissions to levels comparable with a new gas power plant. The government proposes to apply a similar rule to existing coal power plants in 2025, requiring either a substantial reduction in $CO_2$ emissions or their closure.[49]

The emerging UK CCS policy is now focused on higher value-added applications of CCS to industrial sources of $CO_2$; hydrogen production; gas processing and power generation; and negative emissions including biomass.[50]

### Box 3: Changing utility attitudes

Table 2 in Annex 3 details the changes to coal plant ownership in the period since 2000. In most cases the technical operation of power plants has continued without any significant changes in approach following mergers or acquisitions. Over the past decade there have however been some changes in emphasis in corporate strategy that have fed through to policy advocacy and their decisions on coal plant closures.

Notably, the development of conversion projects at Drax, Lynemouth and Uskmouth have all been initiated by independent generators seeking to find a means of continuing operations at individual power plants, which we explore in the accompanying case studies. Here we highlight how the portfolio generators have responded to the evolving policy landscape and the challenge of climate change.

**Scottish Power > Iberdrola (Spain) – PPCA member**
Scottish Power were promoters of the proposed CCS-retrofit project at Longannet power plant and had also proposed that replacement coal plants could be built at Longannet and Cockenzie. Spanish company Iberdrola took ownership in 2006, with a corporate strategy that already saw them moving towards renewables and seeking experience with retail markets. With limited coal generation in their international portfolio, Iberdrola were less convinced by the value of the proposed (expensive) CCS project. The Longannet coal power plant was subsequently closed in 2016, reflecting Iberdrola's intention to close its remaining coal power plants and move fully to renewables. Iberdrola is currently seeking to close the last two coal plants in its portfolio in Spain. Scottish Power has argued that coal should be excluded from the UK capacity market.[51] It has recently announced the intended sale of its gas and hydro assets to Drax, with Scottish Power set to concentrate on wind energy.

**Engie: International Power (France) – PPCA member**
In the UK, Engie had a 75% ownership of Rugeley coal power plant alongside Mitsui, under the name of International Power. The closure of the Rugeley plant in 2016 therefore formed part of Engie's wider strategy to reduce $CO_2$ emissions through the closure or sale of coal power plants. Engie recently announced that is will transform Rugeley coal plant into a sustainable village, consisting of 2000 homes powered by solar panels.[52]

**EDF (France) – PPCA member**
France's largest utility owns two coal power plants in the UK alongside its significant role as the owner of the UK's nuclear power plants. EDF had been viewed as seeking to maintain operations at Cottam and West Burton coal power plants ahead of the proposed entry into service of its new Hinkley Point C nuclear plant and had secured 3-year capacity market contracts with a view to upgrading the plants to fit pollution controls. Subsequently it withdrew from this capacity contract, with indications that these power plants are now being operated on a year-to-year basis depending on capacity contracts.

**E.On > Uniper (Germany)**

E.On purchased Powergen, becoming one of the ‘Big 6’ integrated utilities in the UK. E.On decided to upgrade its Ratcliffe plant with pollution controls, and subsequently criticised the UK government for introducing flexibilities that did not require its competitors to do the same. Following substantial financial losses, in 2016 E.On spun off its fossil assets into a new company vehicle named Uniper to facilitate management and growth of its divergent assets. The closure of its last remaining UK coal power plant at Ratcliffe is therefore being handled by a company with exclusive focus on fossil fuels, rather than a diverse portfolio.

**RWE (Germany)**
RWE purchased Innogy, becoming one of the ‘Big 6’ integrated utilities in the UK. RWE has long had a reputation as one of the most conservative utilities in Europe (reflecting the role of local governments in its ownership structure) and has been slow to respond to both the challenge of climate change and the growth in renewables. In both the UK and Europe, it has advocated against more stringent emissions regulations (for both pollution and $CO_2$). In many cases this was seen as being motivated as an effort to protect its hard coal and lignite power plants in Germany. As owner of the Aberthaw plant, RWE and the UK government were found to be in breach of EU air pollution regulations.

**EPH (Czechia)**
A new entrant to the UK market, EPH has grown over recent years with a strategy centered on purchasing power plants that have been in financial distress and / or with prospects of government subsidy contracts. In the UK, EPH purchased Eggborough power plant when it was seeking subsidies for biomass conversion but this project did not proceed. Closure of the coal power plant was delayed from 2016 to 2018 upon receipt of additional contracts for ancillary services. It is now seeking to construct a new CCGT on site. EPH purchased the Lynemouth power plant from RWE, following approval of the subsidy contract for conversion to biomass.

**SSE (UK) – PPCA member**
SSE completed the closure of Ferrybridge coal power plant in 2016. Its last coal power plant at Fiddlers Ferry is expected to close prior to 2020. SSE did not inherit the same power plant engineering skills base from CEGB as other companies, so has positioned itself as a more progressive company advocating for greater ambition on renewables policy in both the UK and EU.

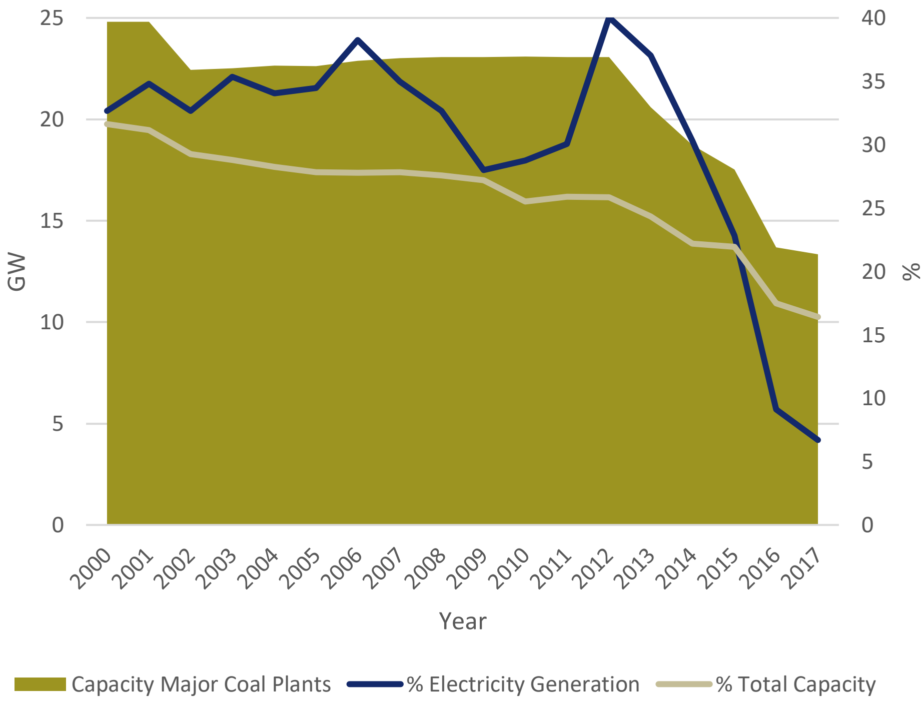
# 5. OUTCOME: THE DECLINE OF COAL

Section 4 provided details on the decisions taken whether to close, convert, or continue operations at individual coal power plants. Here we draw together these elements to provide insights on the aggregate impact on electricity generation from coal.

### The relative declines in Capacity and Generation

Figure 14 shows how the period 2002-2012 saw a plateau of coal power plant at close to 23GW of capacity[53] (left axis). During this period, coal's share of total electricity generating capacity from all sources fell from ~30% to ~25% (light line, right axis). The share of generation from coal fluctuated according to market conditions and relative carbon pricing, with a minimum of 27% in 2009 and a high of 40% in 2012 (blue line, right axis).

*Figure 14: Coal capacity and % share of capacity and generation*



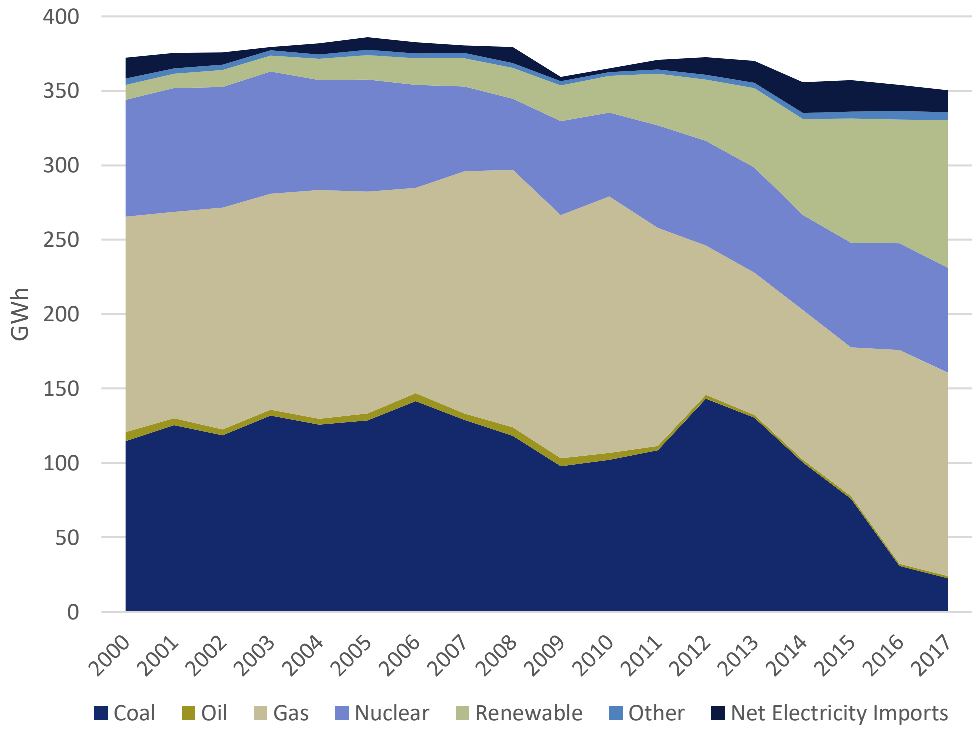

**Source**: DUKES 2018

As discussed above, this peak in coal generation in 2012 resulted from the combination of low coal prices and utilities seeking to maximise use of remaining operating hours from power plants that had opted to close under the LLD ahead of the introduction of higher carbon prices. Utility companies anticipated the arrival of more difficult operating conditions and acted to increase generation (but therefore also increased emissions).

The five-year period from 2012-2017 then saw significant falls in both coal power plant capacity and generation, with generation falling substantially more deeply. Coal capacity fell from 23GW to 13GW due to retirements of power plants under the LCPD, with coal's share of total capacity falling from 26% to 16%. However, generation from coal power plants fell from 40% to just 7% under the influence of the carbon price, setting year-on-year records for the decline in coal generation from 2014 onwards.

This rapid decline in generation is a demonstration of what is possible when there is sufficient alternative lower-carbon capacity available. Figure 15 illustrates how the decline in coal generation has been offset by the growth in renewables and greater dispatch of pre-existing CCGT capacity. It is notable that there has been very little additional gas capacity added to the UK system, with projections for new gas capacity falling by more than 75% between 2015 and 2018.[54]

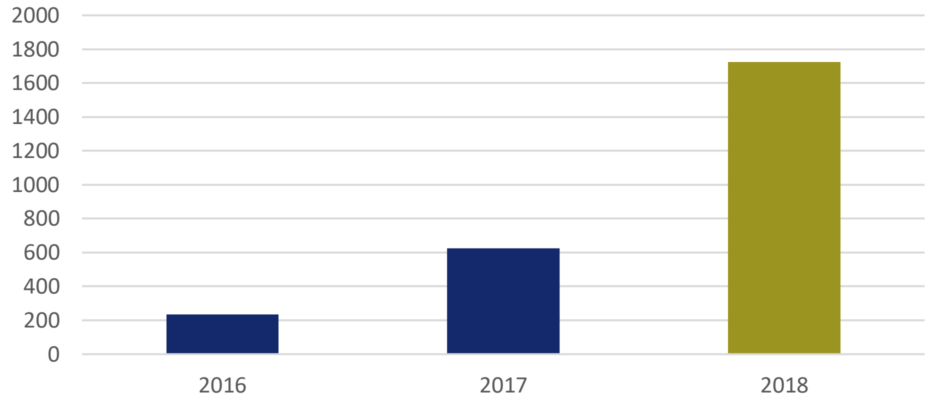
*Figure 15: UK Electricity Use by Source*




**Source**: DUKES 2018

A significant element of this growth in renewables generation has been the arrival of substantial amounts of solar power during the central six months of the year. There is now 13GW of solar capacity in the UK, which increasingly displaces both coal and gas generation, with coal plants now switching to operating principally during autumn and winter months rather than year-round. The rise of solar has been an important factor contributing to the growth in coal-free hours across the UK electricity mix, as show in Figure 16.

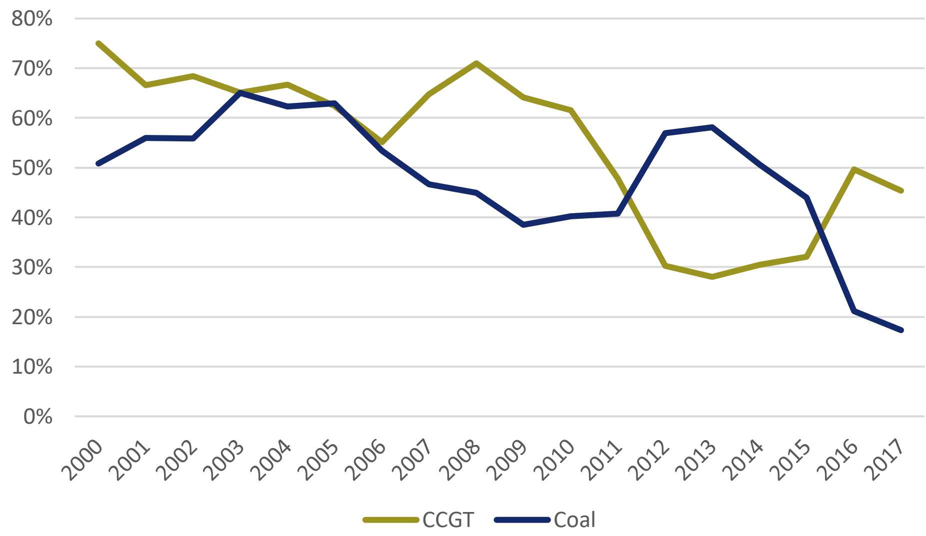
*Figure 16: Coal-free hours 2016 - October 2018.*




**Source**: MyGridGB 2018

At the same time, the growth of renewable energy has also contributed to a reduction in load factors for both coal and gas generation, as shown in Figure 17. This chart also illustrates the competitive dynamic between the two fuels since the year 2000.

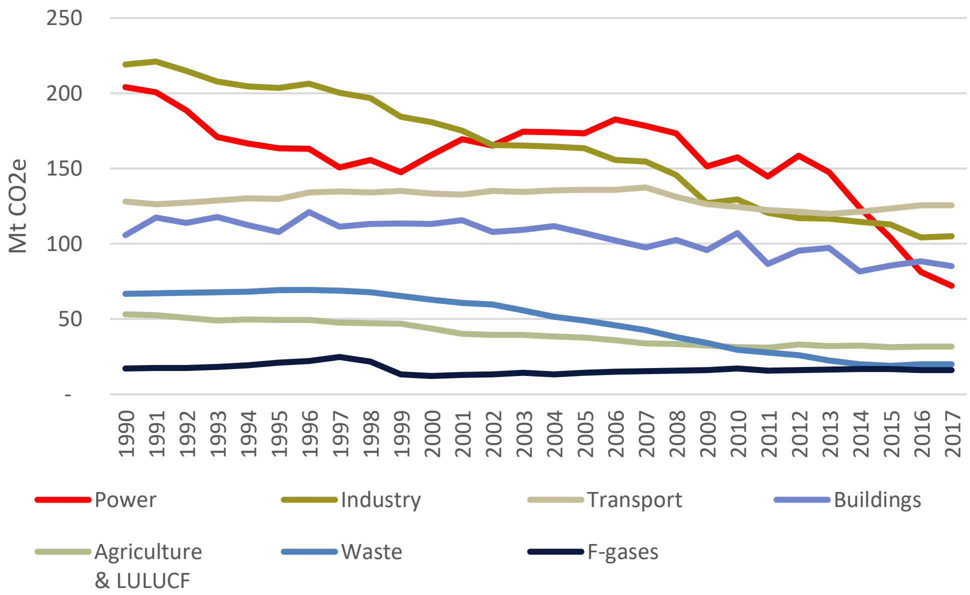
*Figure 17: Load factors for coal and gas power plants*




**Source**: DUKES 5.10

The decline in coal generation in the UK has therefore gone hand in hand with the growth in renewables, contributing to the rapid growth of green economy sectors in the UK, treble the rate of the wider UK economy at 5% in 2016 (compared to 1.8%).[55] It has been the single most important factor in helping the UK to meets its carbon budget targets to date, with emissions reductions falling much more quickly than those of other sectors, as illustrated in Figure 18. Power sector emissions have fallen by over 50% in the years 2012-2017.

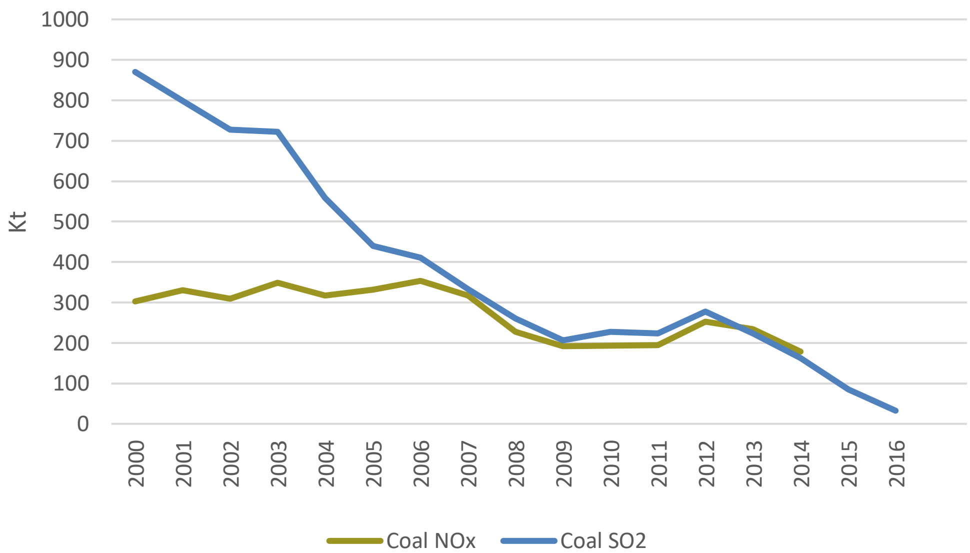
*Figure 18: UK emissions reductions per sector*




**Source**: CCC 2018

Beyond the impact on $CO_2$ emissions, the fall in coal generation has also resulted in substantial reductions in air pollution, as shown in Figure 19. The decline in $SO_2$ has seen the largest overall reductions, reflecting the reduction in coal use (particularly of domestic coal with high sulphur content) and the introduction of FGD technologies.

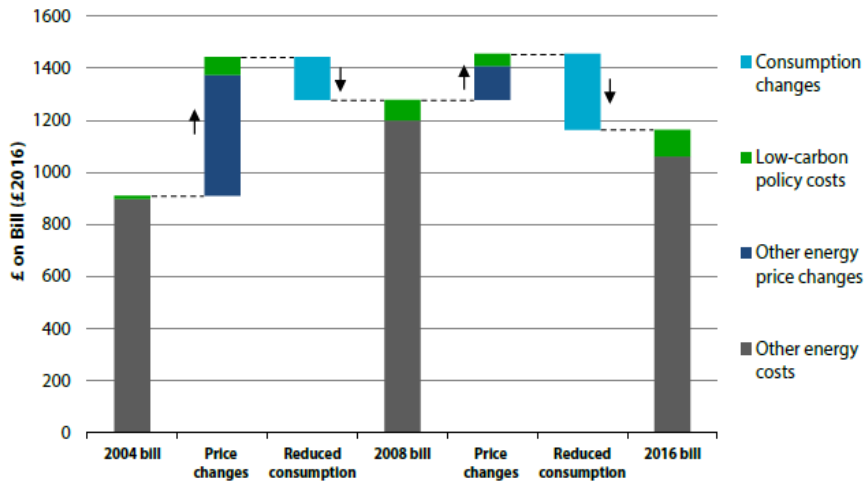
*Figure 19: $SO_2$ and $NO_x$ Emissions from Coal*




**Source**: Aether 2018

Lastly, the decline in coal generation has been achieved in the context of political concern over energy bills for consumers and scrutiny of the extent of policy costs. Figure 20 illustrates how underlying changes in 'other energy costs' (fuel prices, transmission and distribution costs) have been the dominant factor in changes to energy bills. Improvements in energy efficiency have contributed to reduced consumption, helping to reduce overall costs even in the context of where unit prices have increased.

*Figure 20: Changes in annual energy bills 2004 – 2008 – 2016*




**Source**: Committee on Climate Change 2017 [56]

# 6. CONCLUSIONS

This paper has reviewed the evolution of commercial drivers and policy incentives that have contributed to the decline of coal in the UK since 2000 and the delivery of the government's commitment to phase out coal use by 2025.

Overall, we find that the decline in UK coal use resulted from a confluence of market drivers and regulatory interventions that have collectively eroded its position in the electricity mix. These elements were not pre-planned but have resulted in coal phase out being recognised as a logical way forward.

Back in 2009 the government recognised that there could be 'no new coal without carbon capture and storage'. Despite efforts to promote CCS technology it ultimately became evident that there would be no new coal in the UK, meaning that the existing but ageing power plants would not be replaced on a like-for-like basis.

In parallel, successive UK governments have acted to progressively increase the cost of $CO_2$ emissions. This has combined with stricter EU pollution controls to particularly impact the economics of coal generation. These policies have combined with a reduction in demand for electricity, the growth of renewables, and changes to the relative competitiveness of coal and gas in the electricity market.

The commitment in 2015 to phase out coal by 2025 recognised these shifts and sought to provide an orderly pathway towards retirement for coal power plants that would maintain security of supply while encouraging investment in alternative generation technologies.

In considering the strategies of power plant owners and operators in the UK, our analysis has found that coal plant conversion has been a minority strategy compared to the pursuit of plant closure and potential development of new generating capacity:

1. Their preferred option has been **continued operation** of existing coal power plants, until this becomes uneconomic due to market performance, age of components, and / or the need for significant upgrades to meet environmental regulations.
    - Power plants have generally preferred to undertake incremental investments at the time of statutory maintenance outages, rather than large scale investments that need a longer payback period and must consider future generating prospects.[57]
    - The timetables set for compliance with EU pollution control requirements have been essential in providing a pathway for

decisions on investment or closure that applies to all generators. At each stage, power plant operators have argued for looser standards and maximum flexibility.

> Conversely, the availability of capacity payments has provided a pathway to continued operation even in the context of declining revenues from generation.[58]

2. In the majority of cases, coal power plants have then pursued **closure, with consideration of new developments on site**.

   > Owners of coal-fired power plant are beginning to recognise that the value of their asset doesn't reside entirely in the ability to burn coal or even to reuse power plant equipment.

   > Over the past two decades, there has been a shift from consideration of investment in new large-scale coal power generation (and CCS), to CCGT, and now more towards specialised waste fuel units, small scale gas generation, and now also battery storage. This is particularly relevant as the value of providing flexibility to the power system increases compared to the provision of pure baseload power.

   > In many cases, power plants have been demolished but the site has then remained empty with a long delay until the power company decides to release the land for alternative uses.

   > The growth of renewable energy is encouraging some of these sites to be redeveloped, particularly those with coastal locations. For example, the site of the Blyth power plant has lain unused since the plant closed in 2001 and was demolished in 2003. Recently, land remediation experts have worked with the local council to identify the potential reuse of the site and its dock facilities as a centre for offshore wind supply chains.[59] [60]

   > Most recently, in November 2018 Engie has announced plans to demolish Rugeley power plant and construct a new solar village on the site.[61]

3. Only in a minority of cases have existing coal power plants opted for **conversion to operate existing power plant assets using alternative fuels.**

   > Biomass conversion has a mixed record, with technically successful conversions undertaken at Drax, but fires at Ironbridge and Tilbury.

   > Subsidies for biomass conversion are now no longer available and there are growing concerns over environmental and climate impacts, making further conversion projects unlikely after the conclusion of the Lynemouth project.

> Conversion to waste pellets is now being proposed for the small power plant at Uskmouth, with claims that this could be a breakthrough technology for existing coal power plants.

> Drax proposes to convert the last two coal units to provide the steam turbines of new CCGT units.

> Alternative uses of existing power plant equipment are now being developed by technology providers (such as reuse of sites for thermal energy storage),[62] and may yet be considered by the remaining UK power plants.

4. Over recent years, power plant operators have generally sought to **redeploy power plant staff to other roles** within the company[63] (including management of site closure and demolition) and / or have offered retirement and retraining packages to workers.

> Staff costs have become a declining portion of the ongoing cost base of power plant operations. The visibility provided by the coal phase out pathway has enabled forward planning of these human resources and increased use of contractors to match changes to the operational profile across the year.

> The UK government has a limited role in addressing the local impacts of power plant closures. It has assisted local councils with the impact of reduced local tax revenues[64] and encouraged regional economic redevelopment.[65]

> All UK deep coal mines had already closed, with coal consumption now dominated by imports. There have been reductions in demand for coal transit by rail,[66] however this has impacted a much smaller employment base than previously occurred through the mine closure programme.

## The coal phase out commitment: both following and leading

The announcement in 2015 of the UK commitment to phase out coal by 2025 reflected a recognition from UK government that there would be no replacement of existing, ageing coal power plants with new coal (including with CCS). Shifting dynamics in the electricity market (particularly reduced demand and lower gas prices) combined with the impact of carbon pricing to make coal plants increasingly uneconomic. It was therefore recognised that a continued decline in coal use and further retirement announcements were increasingly likely.

The UK government believed that this situation required a coherent pathway to the cessation of coal use in a way that could help encourage investment in alternative capacity.[67] [68] By announcing a commitment to coal phase out, the UK government sought to provide clarity on the future direction of travel while leaving the market to decide on individual investments. In light of the UK's history of coal use this commitment also provided a significant international statement of intent and has helped catalyse similar commitments from other leading governments.

Ultimately, the UK government's commitment in 2015 to phasing out coal by 2025 reflected a widespread recognition that there was no future for coal, continuing trends in coal use evident since the industry restructuring and privatisation in the 1980s. Whereas a decade earlier there was still a widespread perception that coal was a cheap source of electricity generation, the necessity of dealing with air pollution and $CO_2$ emissions meant that coal was now viewed as a more expensive form of generation compared with the declining cost of renewables.

Our analysis of the UK experience points to the central importance of government policy in providing a pathway for reductions in coal use and power plant retirement while enabling individual plant operators to decide on retirement decisions. Timetables for compliance with pollution control regulations have required a response from all power plant operators, while the introduction of effective carbon pricing has provided a market signal and boosted competition between fuels and technologies. The coal phase out commitment brings these elements together and provides clarity on the intended ultimate outcome, even ahead of legislation being introduced.

# ANNEX 1. CASE STUDY: LARGE COAL PLANT CONVERSION: DRAX

Drax power station was built in two phases, each involving three 660MW turbines. The first phase was completed in 1974 and the second in 1986. With a total capacity of nearly 4GW, it was the largest coal-fired power station in Europe for many years. It was initially supplied with coal produced from local mines but, as these pits were progressively closed during the 1980s and 1990s, it was increasingly supplied by imported coal via ports on the east coast of Britain.

The first major upgrade to the power station occurred between 1988 and 1995 when FDG plant was installed. This decision had been taken before privatisation as an important contribution in the UK’s efforts to tackle acid rain.

At privatisation, the ownership of Drax was transferred from the CEGB to National Power. Drax power station was sold by National Power to AES Corporation in 1999 as part of the divestment programme designed to address concerns about high wholesale prices. As wholesale prices fell at the turn of the century, AES was unable to finance the debt burden and the power station fell into administration in 2003. Following a refinancing package, ownership passed to the newly formed Drax Group in 2005, who have remained in control of the power station ever since.

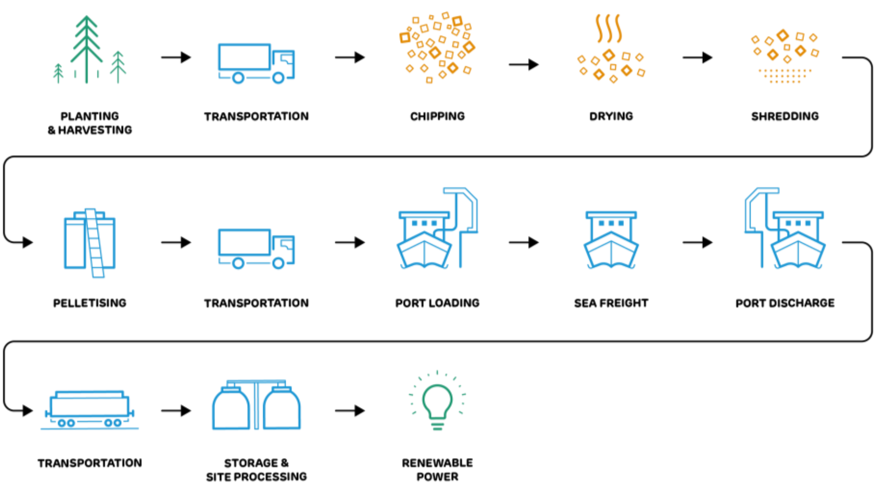
Once Drax Group had been created, it could focus on developing a long-term growth strategy for the business. Initially, this involved proposals to build two new facilities to operate alongside the existing coal-fired power station. Plans for a 300MW dedicated biomass plant were submitted to the Government in 2009 (it was also proposed to build a further two 300MW plants at nearby Hull and Immingham ports). Proposals were also made to take advantage of UK and EU CCS commercialisation funding to build a new 426MW oxy-fuelled coal-fired power station. This special purpose vehicle consortium “the White Rose CCS project” received funding for front end engineering design studies in 2014. However, a decision by the UK Government in 2015 to abandon funding for this CCS programme brought this project to an end. Prior to the cancellation of the project Drax had announced that it would step back from being an active member of the consortium, but would still encourage its co-location on site.

Whilst no major upgrades were required to ensure compliance with the LCPD (since FGD had already been installed), Drax Group continued to invest in the original coal-fired power station to improve its competitive position in the market. Between 2007 and 2012, a major project was undertaken to replace high- and low-pressure turbines with new high-efficiency designs.

Alongside on-going investment in the plant, Drax launched a research and development programme exploring the viability of using alternative fuels in the coal boilers. Locally sourced biomass had been mixed with the coal at low levels from 2003 to enable Drax to claim renewable obligation certificates. A pilot direct injection facility was built in 2005 that involved blowing crushed wood pellets into coal fuel lines from two of the power station's 60 mills. This was followed by a dedicated £50m 400MW biomass co-firing facility commissioned in 2010, capable of supplying up to 1.5million tonnes per year of biomass directly into the boilers.

The decision to convert three coal units to 100% biomass was taken while the UK Government was considering replacing the existing renewable obligation subsidy scheme with contract for difference feed in tariffs (FiTs). The first two units, commissioned in 2013 and 2014, received accreditation under the RO scheme. However, the third unit was awarded one of the initial Contracts for Difference (CfD) and was commissioned in 2016. This supportive policy framework enabled Drax to commit to a £700m investment in the three-unit conversion project and associated infrastructure including storage on site for 300,000 tonnes of wood pellets – enough to power the station for roughly two weeks – and dedicated handling facilities for biomass imports coming through the UK ports of Hull, Immingham, Liverpool and Tyne.

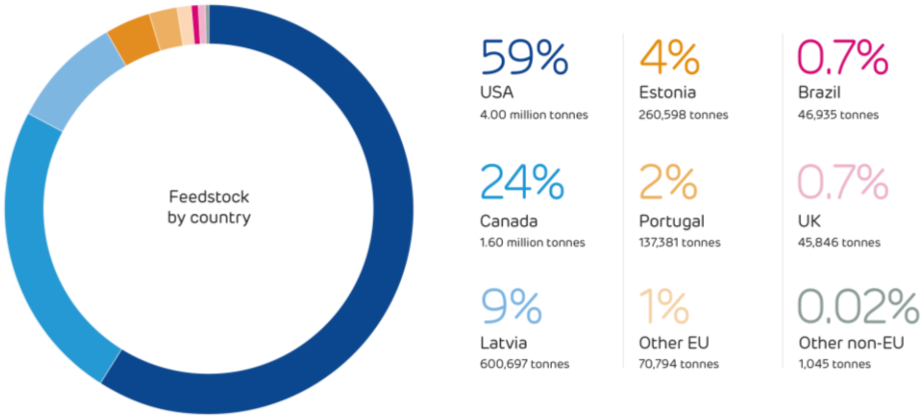
*Figure 21: Drax biomass supply chain*




**Source**: Drax

A key success factor for the biomass conversion project was the ability to source biomass sustainably at large volumes (over two million tonnes per unit annually) – see Figure 21 for a schematic description of the biomass supply chain. Roughly half of the £700m investment was spent developing a dedicated supply chain in the southern US, sourcing wood fibre from large working forests. This involved the construction of two new plants in Louisiana and Mississippi to pelletise the wood fibre and an export facility in Baton Rouge to ship the pellets to the UK. These facilities enabled Drax to self-supply roughly one million tonnes of pellets per annum, with the remainder coming from other pellet suppliers in North America and to a lesser extent Europe. A third pellet plant was acquired by Drax in 2017, enabling it to self-supply an additional 450,000 tonnes. Drax biomass feedstock mix by country of origin for 2017 is summarised in Figure 22 below.

*Figure 22: Biomass feedstock sources*




**Source**: Drax

In the period up to 2015, Drax had to decide on the investment strategy for the remaining three units still operating on coal, including how to approach the requirements necessary to comply with the IED from 2020. Drax decided to adopt a relatively low-cost approach to IED compliance based on fuelling strategy and a reduction in the expected output at these units. However, by 2017, the economics of coal generation had become less favourable.

By this time, contracts for difference feed in tariffs were no longer available for new biomass conversions, however the Government decided to allow power stations to receive renewable obligation certificates for biomass burnt within any unit on the station provided the total across multiple units remained within an overall cap. This change, coupled with reductions in the costs of conversion through leveraging existing infrastructure on site, led Drax to decide in early 2018 that it would fully convert a fourth unit to biomass, which was completed in August 2018. The intention is to operate this fourth unit with lower availability than the three existing converted units, to capture periods of high market price and allow optimisation of renewable obligation certificates across the three accredited units.

Drax now has only two units still running on coal. However, given the reducing load factors of these units and the Government decision to end coal generation by 2025, it is considering repowering these to form part of a new CCGT alongside investment in large batteries. If these proposals are taken forward, it would mark the end of a 15-year journey from a six-unit station operating entirely on coal to being completely coal-free.[69]

In parallel to the change from coal to biomass feedstocks, Drax Group has sought to diversify its commercial portfolio away from being a single power plant company (albeit a very large one supplying 6% of UK electricity). It has developed Haven Power as a supplier of electricity to business, and Opus Energy as a supplier of both gas and electricity in partnership with 2,300 small generators. Drax Biomass handles the company's procurement, manufacturing and shipping of wood chips – a form of vertical integration back up the nascent supply chain.[70]

In October 2018, Drax Group announced that it has agreed to acquire Scottish Power's portfolio of pumped storage, hydro and gas-fired generation from parent company Iberdrola. This is currently subject to Drax shareholder approval and regulatory clearance by the Competition and Markets Authority. This purchase further diversifies the company away from baseload power generation and dependence on biomass subsidies, helping it to create a platform for continued operations as a provider of flexibility services across the electricity grid.[71]

# ANNEX 2. CASE STUDIES OF SMALLER COAL PLANT CONVERSION: USKMOUTH & LYNEMOUTH

### Uskmouth

Uskmouth power station was built by the CEGB in 1959 and comprised three 120MW units. It was transferred to National Power at privatisation and, along with other plant of this size, closed in 1995 as part of capacity management strategy. However, the site was not demolished (as was the case with other similar power stations) and the site was acquired by AES in 1998 who invested £120m in FGD and low NOx burners to make it compliant with LCPD. AES re-opened the station in 2001 but went into receivership in 2002 as part of the group's financial difficulties.

Uskmouth was acquired by Welsh Power (initially Carron Energy) in 2004 who sought to optimise short term earnings and take advantage of relatively low coal prices. They did not invest in any major upgrades and sold the plant to SSE in 2009. SSE decided not to invest to comply with the IED and withdrew the first unit from operation in 2013 before closing the whole plant in 2015.

The site with two operational units was acquired in 2016 by Hong Kong-based SIMEC (later re-financed as SIMEC Atlantic Energy).[72] They initially planned to extend the life of the plant by converting the two remaining units to biomass before switching to a focus on energy from waste. The project is currently at the front-end engineering and design (FEED) stage[73] and the remaining two coal units were mothballed in April 2017 in preparation for the conversion. The conversion is expected to take 18 months post completion of the FEED study and has a target of first production in Q4 2020.[74] Thereafter, the expected operating lifetime is 20 years.

The current plan is to export 220 MW of baseload power to the grid using an end-of-waste energy pellet. Dutch recycling firm N+P is working with SIMEC to design a pellet production plant at the site. The pellets will be created from biogenic waste and non-recyclable plastic. It calls this fuel 'Subcoal' and N+P claims it will deliver an average calorific value of 20 mega joules per kg. Milling trials have been conducted on the N+P Subcoal pellets using vertical spindle roller mills in Germany.

The plant has a 20-year power purchasing agreement in place with GFGAlliance's Liberty Steel, [75] which has a steel plant in Newport close to the Uskmouth site. It also has a 20-year fuel supply agreement but does not have any government subsidy. The company believes the plant will have a low levelised cost of generation which will allow it to deliver high margins on power sales.

### Lynemouth

Lynemouth power station was built in 1972 to supply an aluminium smelter. It comprised three 140MW units, taking coal from local Ellington pit. It operated purely on coal until 2004 when it began co-firing with biomass to take advantage of the Renewable Obligation subsidy scheme.

Rio Tinto Alcan decided against making the relevant upgrades to comply with the LCPD and, in 2010, the European Court of Justice ruled that the UK Government was in breach of this legislation and Alcan would have to spend money to comply. Alcan considered the site for pre-combustion CCS in 2009 but the proposal did not progress and, instead, they chose to develop plans for biomass conversion as their route to achieving a long-term life for the plant.

Subsequently, however, the aluminium plant closed in 2012 and the power station was sold to RWE npower. RWE obtained an early CfD FiT in 2013 to support the conversion to biomass and this subsidy was approved by the European Commission in 2015. The plant was opted-out of the IED and ceased coal generation in December 2015.[76] It was then sold by RWE to Czech firm EPH in 2016 to progress the biomass conversion. The project is now in the commissioning phase although no date for full commercial operation has been published.

Once operational the station is intended to operate at baseload and generate 420MW, with 390MW export of low carbon electricity to the national grid, achieving an annual output of about 2.3TWh. It is estimated that the Lynemouth biomass power plant will consume approximately 1.4 million tonne (Mt) of wooden pellets a year. The pellets will be imported primarily from the US and Canada and shipped to the UK by sea. They will be received at the new biomass import terminal built at the Port of Tyne, Newcastle, UK.

Lynemouth Power Limited (LPL) signed an off-take contract with Enviva Partners, a company based in the US, in June 2016 to supply 800,000t a year of wooden pellets for the plant. It was intended to start supplying the pellets from the third quarter of 2017 (although first deliveries were not received until February 2018) through to the first quarter of 2027.

Engineering Company Sir Robert McAlpine is undertaking the contract to provide a new materials handling and storage system at Lynemouth. The complete replacement of coal, as the station’s fuel source, by biomass, predominantly wood pellets, has meant that a completely new intake and 50,000 tonne storage system has had to be provided. The new facilities include a new rail unloading point, a new road unloading point and a new bulk storage silo facility. Spencer Group will install the biomass rail-loading facility at the port. The facility will be used to convey the pellets to three new silos with a storage capacity of 25,000t each. Two conveyors will mechanically discharge the material from the silos to a rail-loading facility. GB Rail freight will deliver more than 37,000t of pellets on up to 27 trains a week from the Port of Tyne to the Lynemouth power station, under a rail haulage contract signed with LPL.

Box 4: *Power Technology* Profile: Lynmouth conversion contractors[77]

*Ramboll has been appointed to provide engineering consultancy services for the plant's conversion to biomass. The company will provide owner's engineer services under the contract.*

*The combustion and emissions systems for the conversion will be supplied by Doosan Babcock, a company based in the UK.*

*Clyde Bergemann Power Group (CBG) was subcontracted by Doosan Babcock to supply the former's DRYCON dry bottom ash handling system, which is a steel plate conveyor, to replace the existing submerged scraper chain in each boiler. DRYCON uses ambient air for cooling the bottom ash, unlike the old submerged scraper chain that uses water for ash conveying.*

*CBG will has also delivered pneumatic fuel conveying system for the plant to convey the wooden pellets from the silos to the inlet of the fuel mills located 80m-200m away from the boilers.*

*The fuel handling system for the conversion project has been engineered and designed by Fairport Engineering, a company based in Adlington, England. The civil works for the same were provided by Clancy Consulting.*

*Emerson has been appointed as the main automation and electrical contractor for the project. Its contractual scope includes demolition, engineering, installation, start-up, and commissioning. It will further be responsible for co-ordination of work among multiple suppliers and contractors working for the project.*

*Emerson will install a single integrated automation platform for the turbine, boiler, fuel handling, balance-of-plant processes, and electrical systems at the plant. It will also install the Emerson Ovation® control system at the plant to monitor the moisture content in the pellets and accordingly adjust the combustion air in order to improve the plant efficiency and lower maintenance costs.*

*Eversheds provided legal advisory services for the contracts awarded in relation to the conversion project.*

# ANNEX 3: UK COAL PLANTS SINCE 2000

*Table 2: UK Coal power plants operating since 2000*

| Name | Installed Capacity (MW) | Status | Plant Age | Fuel | Ownership | Notes | Date of (planned) Closure |
|---|---|---|---|---|---|---|---|
| Blyth B | 1250 | Closed | 1962 - 2001 (39 years) | Coal | [CEGB > National Power] > Innogy Plc | Closed for commercial reasons. New coal plant proposed on site but not built. | Closed in 2001 |
| Drakelow C | 1450 | Closed | 1964 - 2003 (39 years) | Coal | [CEGB] > TXU PowerGen > E.On | Closed for commercial reasons. | Closed March 2003 |
| High Marnham | 945 | Closed | 1959 - 2003 (44 years) | Coal | [CEGB] > TXU PowerGen > E.On | Closed for commercial reasons. New coal plant proposed on site but not built. | Closed in 2003 |
| Kingsnorth | 1940 | Closed | 1970 - 2012 (42 years) | Coal and oil. Co-fired biomass. | [CEGB >] PowerGen > E.On | Opted out of LCPD, took LLD of 20,000 hours. New coal plant proposed, became an entry to CCS Competition, but not built. Severe fire at units 1 and 2 ended their operation. | Closed Dec 2012 |
| Cockenzie | 1152 | Closed | 1967- 2013 (46 years) | Coal | [SSE] > Scottish Power > Iberdrola | Installed boosted overfire air technology in 2005-2007. Opted out of LCPD, took LLD of 20,000 hours. New coal plant proposed on site but not built. | Closed March 2013 |
| Didcot A | 1958 | Closed | 1972- 2013 (49 years) | Coal and gas. Co-fired biomass. | Innogy > RWE Innogy > RWE Npower Plc | Co-fired biomass. Between 2005-2007, installed overfire air systems but opted out of LCPD and took LLD of 20,000 hours. | Closed March 2013 |
| Tilbury B | 1029 | Closed | 1970 - 2013 (43 years) | Coal | Innogy > RWE > RWE Npower Plc | Opted out of LCPD, took LLD of 20,000 hours. New coal plant with CCS proposed on site but not built. Biomass conversion undertaken prior to end of LLD with view to re-permitting as new plant. A fire in 2013 resulted in the closure of two units and abandonment of biomass project. | Closed Aug 2013 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ferrybridge C (Units 1 & 2) | 980 | Closed | 1966 - 2014 (48 years) | Coal | Edison Mission Energy > AEP > American Electric Power > SSE | Fitted with FGD in 2005 to comply with LCPD. Proposal for new coal plant with CCS in 2006 which was not built. Boilers were fitted with boosted overfire air technology in 2008. In 2013 the plant operators decided not to comply with the IED. | Closed March 2014 |
| Ferrybridge C (Units 3 & 4) | 980 | Closed | 1966 - 2016 (50 years) | Coal and co-fired biomass | Edison Mission Energy > AEP > American Electric Power > SSE | As above. Units 3 and 4 fitted FGD in 2009 to meet LCPD + SSE signed a 5 year agreement with UK Coal. Decided not to comply with IED and closed before it came into force. Serious fire broke out in unit 4 in 2014 causing irreparable damage. A new multifuel plant become operational on site in 2015, with a further multifuel project under development. | Closed March 2016 |
| Ironbridge B | 970 | Closed | 1970 - 2015 (45 years) | Coal Conversion to biomass. | TXU > PowerGen > E.On | Opted out of LCPD and took LLD of 20,000 hours. Converted both units to biomass in 2012, reduced to 360MW in April 2014 after severe fire in unit 2. Plant decided to not go through re-permitting and instead closed. | Closed Nov 2015 |
| Lynemouth | 420 | Closed. Converting to biomass | 1970 - 2015 (45 years) | Coal Converting to biomass | Alcan > Lynmouth Power (RWE) > EPH | Installed FGD in 2011 to comply with LCPD 2. Decided to not comply with the IED and entered LLD of 17,500 hours. Biomass conversion received EU State Aid approval in December 2015, due to be connected to the grid in 2018. | Closed 2009-2012. Reopened 2013 - 2015. Converting to biomass in 2018 |
| Longannet | 2304 | Closed | 1970 - 2016 (46 years) | Coal | Scottish Power > Iberdrola | New coal plant with CCS proposed on site but not built. Retrofit CCS project proposed for UK CCS competition - was last remaining project but not funded by government due to cost. Units 1-3 fitted with FGD in 2012-2013. Unit 4 employed a low sulphur coal strategy. Decided not to comply with the IED as uneconomic to upgrade. Failed to win tender to provide grid stability services. Did not bid for capacity contracts. Carbon and grid costs also contributed to closure. | Closed March 2016 |
| Rugeley B | 1006 | Closed | 1970 - 2016 (46 years) | Coal | TXU > International Power (Engie / Mitsui) > Engie | Fitted FGD in 2007 to comply with LCPD. Entered TNP delaying compliance with IED until June 2020 but failed to secure capacity contract for 2018-2021. Carbon costs contributed to closure. | Closed June 2016 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Eggborough | 1960 | Closed | 1967 - 2018 (51 years) | Coal | British Energy > Eggborough Power (EP Power Europe and Energeticky) > EPH | Fitted FGD to units 3 and 4 in 2005 and boosted overfire air technology between 2005-2007 to comply with LCPD. Decided to not comply with the IED and entered LLD of 17,500 hours. Delayed planned closure to provide partial back-up power during winter 2016-17 under SBR. Secured 1 year contract for 2017-18. | Closed Sep 2018 |
| Uskmouth | 393 | Operational / Converting to waste | 1970 - present (48 years) | Coal Previously co-fired biomass. Conversion to waste proposed. | [CEGB > National Power >] AES > Uskmouth Power (Carron Energy / Welsh Power) > SSE > SIMEC | Plant closed and reopened multiple times under various owners. Fitted FGD in 2007 to comply with LCPD. SIMEC Atlantis now seeking to convert units to burn energy derived from non-recyclable waste products. | Closed in March 2013 / 2014 but reopened by SIMEC. Not generating in 2018. |
| Kilroot | 662 | Operational | 1970 - Present (48 years) | Coal | AES | Fitted FGD in 2005 to comply with LCPD. Opted into the TNP. Northern Ireland has devolved powers on energy, meaning Kilroot does not fall under the remit of the GB coal phase out policy. Failed to secure capacity contract in SEM auction in 2018. Closure was anticipated but has now been postponed following an exchange of capacity contracts. | Closure considered in 2018 but postponed following exchange of capacity contracts. |
| Fiddlers Ferry | 1980 | Operational | 1971 - Present (47 years) | Coal and co-fired biomass | Edison Mission Energy > American Electric Power > SSE | Fitted FGD in 2006 to comply with LCPD. Entered the TNP, but likely to close by 2020 rather than upgrade, with one unit possibly at an earlier date. Had proposed earlier closure but awarded SBR and black start contracts. Failed to secure T-4 contracts for 2019-20 and 2020-21. | Likely to be before 2020 |
| Cottam | 2008 | Operational | 1969 - Present (49 years) | Coal | London Electricity > London Power Company > EDF | Fitted FGD in 2006 to comply with LCPD. Entered TNP delaying IED compliance until June 2020 but withdrew from 3-year capacity contract that would have funded upgrade investment. No clear signs of compliance with IED. Secured capacity contract for 2018-2019, but needs to bid in T-1 for 2019-20. | Likely to be before 2025 - may move to peak load derogation. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Aberthaw B | 1610 | Operational at reduced hours | 1971 - Present (47 years) | Coal and co-fired biomass | Innogy Plc, RWE Innogy > RWE Npower | Co-fired biomass following introduction of Renewables Obligation. Fitted FGD to comply with LCPD. Unlawfully claimed a derogation for burning low volatility fuels that it did not in fact burn. Secured capacity contract for 2018-21, not for 2022. Entered into the TNP, delaying compliance until June 2020. Has been running reduced hours since April 2017. | Legal situation unclear - may move to peak load derogation. Has Capacity Contract for 2020-21. |
| West Burton | 2012 | Operational | 1970 - Present (48 years) | Coal | TXU > London Power Company > EDF | Fitted FGD in 2001 to comply with LCPD. Entered TNP delaying compliance until June 2020 but withdrew from 3-year contract. 3 out of 4 units have a contract for 2020-21, but failed in T-4 bid for 2022. | 500 by 2020 and 1500 by 2023. |
| Ratcliffe | 2000 | Operational | 1970 - Present (48 years) | Coal | [CEGB] > PowerGen > E.On > Uniper | Fitted boosted overfire air technology in 2005 and FGD in 2006 to comply with LCPD. Chose to comply with the IED but also entered the TNP. Invested in SCR in 2011 to meet pollution control standards, enabling operation into 2020s. Secured capacity contract for 2018-22. | 2025 in line with government policy |
| Drax Units 1-3 | 1980 | Operational | 1973 - Present (45 years) | Coal and co-fired biomass > Now biomass | [CEGB > National Power] > AES > Drax Power | Fitted FGD prior to 2000 and installed boosted overfire air technology in 2008. Chose to comply with the EU IED, fitting SNCR scrubbers to unit 3 and entered the TNP. Units 1 and 2 converted to biomass in 2013 and 2014, with unit 3 in 2016. | Converted to biomass to 2016 |
| Drax Units 4-6 | 1980 | Operational | 1986 - Present (32 years) | Coal. Unit 4 converted to biomass. | | Fitted FGD prior to 2000 and installed boosted overfire air technology in 2008. Entered TNP delaying compliance until June 2020. Chose to comply with EU IED, fitting SNCR scrubbers. Secured capacity contract for 2018-22. Unit 4 converted to biomas in 2018. Drax proposes to convert the remaining two units proposed to gas plus investment in energy storage. | Drax on record as saying conversion from coal could be completed by 2023. |

# ABOUT THE AUTHORS

**Chris Littlecott – Programme Leader, Fossil Fuel Transition**

Chris Littlecott leads E3G's activities on the transition from coal to clean energy, with a focus on the growing international engagement on coal phase out. He had been closely involved in UK coal policy since 2008, working as a policy analyst, civil society advocate and advisor to government.

Chris spent 4 years as a senior policy advisor at the think tank Green Alliance where he published the October 2008 publication 'A last chance for coal: making CCS a reality' and convened the September 2009 UK CCS dialogue of over 40 organisations. From 2008 to 2011 he served as the UK board member and Vice President of European Environmental Bureau, Europe's largest network of environmental organisations. He has also worked as policy research associate with the Scottish Carbon Capture and Storage academic network and is a member of the advisory council of ZEP - the European Technology Platform for CCS.

**Louise Burrows – Policy Advisor, Fossil Fuel Transition**

Louise Burrows works as a Policy Advisor on E3G's activities supporting the transition from coal to clean energy. Her work focuses on how public policy and international diplomacy can support this shift away from coal.

Prior to joining E3G, Louise worked for the UK energy regulator Ofgem. Her role within the Sustainable Energy Futures team involved carrying out the process of 'Horizon Scanning' to determine future energy system trends and drivers of change, used to inform policy. This followed a period of working for the Enforcement team, where her role involved the monitoring of compliance with regulatory standards and licence conditions across the UK energy market.

**Simon Skillings – Senior Associate**

Simon Skillings has nearly 35 years' experience working in the energy industry and has developed an advanced knowledge of EU/UK energy markets, policy and regulation. Much of this time has been spent in a variety of strategic, regulatory and policy roles for Powergen and E.ON UK, culminating in a 5 year period spent as Director of Strategy and Energy Policy.

In 2007, he established his own energy consulting company, Trilemma UK Ltd., and has subsequently provided advice on investment and policy issues for a range of private companies, UK Government and the regulator OFGEM. He is an associate teacher at Warwick Business School where he lectures on Business, Policy and Regulation for the executive MBA programme.

# LIST OF ACRONYMS

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| BAT | Best Available Techniques |
| BATNEEC | Best Available Technology Not Entailing Excessive Cost |
| BREF | Best Available Technology Reference Document |
| CCA | Climate Change Act |
| CCC | Committee on Climate Change |
| CCGT | Combined Cycle Gas Turbine |
| CCS | Carbon Capture and Storage |
| CEGB | Central Electricity Generating Board |
| CfD | Contracts for Difference |
| CM | Capacity Market |
| CPS | Carbon Price Support |
| EMR | Electricity Market Reform |
| EU | European Union |
| EU ETS | European Union Emissions Trading System |
| FEED | Front End Engineering and Design |
| FiTs | Feed in Tariff |
| FGD | Flue Gas Desulphurisation |
| IED | Industrial Emissions Directive |
| LCPD | Large Combustion Plants Directive |
| LLD | Limited Life Derogation |
| NECD | National Emission Ceilings Directive |
| NERP | National Emissions Reduction Plan |
| PLD | Peak Load Derogation |
| PPCA | Powering Past Coal Alliance |
| RO | Renewables Obligation |
| TNP | Transitional National Plan |
| SBR | Supplemental Balancing Reserve |
| SCR | Selective Catalytic Reduction |
| SEM | Single Electricity Market |
| SNCR | Selective Non-Catalytic Reduction |

# ENDNOTES

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[1] The Great Britain grid covers England, Scotland and Wales. The electricity grid in Northern Ireland is managed as part of the Single Electricity Market shared with the Republic of Ireland.

[2] In undertaking this study we found that there was no publicly available overview of coal power plant decisions, so have therefore created our own overview resource. We will look to further develop this going forward.

[3] **Revolvy: Holborn Viaduct first coal-fired power station**

[4] Historical coal data in this section all drawn from DECC (2008) DUKES 60th Anniversary paper

[5] These new coal-fired power plants set multiple records for being the largest size or highest efficiency in Europe.

[6] **UK Parliament (2013) Nuclear Energy Statistics**

[7] **IET and Parliamentary Group for Energy Studies (2012) UK Energy Policy 1980-2010. A history and lessons to be learnt**

[8] **IET and Parliamentary Group for Energy Studies (2012) UK Energy Policy 1980-2010. A history and lessons to be learnt**

[9] **World Bank (2018) Electricity production from coal sources (% of total)**

[10] **DECC (2015) Amber Rudd's speech on a new direction for UK energy policy**

[11] The Great Britain grid covers England, Scotland and Wales. The electricity grid in Northern Ireland is managed as part of the Single Electricity Market shared with the Republic of Ireland.

[12] **UK Guardian (2016) UK energy from coal hits zero for first time in over 100 years**

[13] **BBC News (2017) First coal-free day in Britain since 1880s**

[14] **BBC News (2017) Britain powers on without coal for three days**

[15] **MyGridGB (2018) Coal Tracker**

[16] **MyGridGB (2018) Coal Tracker**

[17] Employment in coal mining shrank throughout the post-war period. In 1953 there were still 713k workers, falling to 528k in 1963; 252k in 1973; 148k in 1983; 10k in 1993; and 6k in 2003.

[18] **Carbon Brief (2015) Mapped: how the UK generates it electricity**

[19] For a longer discussion of the dynamics of privatization, see Dieter Helm (2004) **Energy, the State, and the Market: British Energy Policy since 1979**

[20] **UK Government (2002) Our energy future, creating a low carbon economy**

[21] Presentation to CBI Climate Summit, 2 December 2008, by Paul Golby, CEO of E.ON UK**: Slides**

[22] **UK Legislation (2008) Climate Change Act**

[23] **CCC (2009) Meting carbon budgets – the need for a step change**

[24] For further discussion of this see **E3G (2015) G7 Coal Phase Out: UK. A Review for Oxfam**

[25] **The Guardian (2009) No new coal without carbon capture, UK government rules**

[26] A new build CCS unit at the proposed new Kingsnorth power plant in southern England, and a retrofit of CCS to the existing Longannet power plant in Scotland.

[27] For an overview of the relative Levalised Costs of Electricity from different generating sources see BEIS (2016) **Electricity Generation Costs**

[28] See Peter Brown (2015) **From FGD to CCS**, Transform / Institute of Environmental Management and Assessment.

[29] See for example Nils Markusson (2012), **The politics of FGD deployment in the UK (1980s-2009),** UK Energy Research Centre.

[30] Details of Emissions Limit Values for all sizes of power plant are available in Annex V of **Directive 2010/75/eu on Industrial Emissions (Integrated Pollution Prevention and Control).**

[31] See Guardian (2014) **'Old coal' subsidy loophole to be closed by UK government**

[32] **DECC (2015) Government announces plans to close coal power stations by 2025**

[33] Originally, the government intended to establish an increasing minimum carbon price that British electricity generators would pay. Starting from £15.70 in 2013, this minimum price was due to escalate by roughly £2/year until it reached £30 in 2020. From there it was supposed to by £4/year until it reaches £70 by 2030. See - **Sandbag (2016) The UK carbon floor price.**

[34] **BBC News (2015) Party leaders make joint climate commitment**

[35] The reference to 'unabated' refers to the potential application of CCS, a continuation of the UK regulatory framework for new power plants that had been put in place over the past decade.

[36] **DECC (2015) Amber Rudd's speech on a new direction for UK energy policy**

[37] **BIES (2016) Consultation on coal generation in Great Britain: the pathway to a low-carbon future**

[38] **BEIS (2018) Government response to unabated coal closure consultation**

[39] See **Bloomberg (2018) Drax CEO Gardiner interviewed at Bloombeg NEF summit** and **Reuters (2018) Drax plans to cut cost of biomass electricity by a third**

[40] **Biofuelwatch** and **RSPB** provide insight and analysis on biomass woodchip production.

[41] **RSPB - Bioenergy: A burning issue**

[42] **NRDC (2017) Solar and wind cheaper than biomass to reliably power the UK**

[43] Committee on Climate Change (2018) **Biomass in a low-carbon economy**

[44] Timera Energy Blog (2016) **The impact of rising coal prices**

[45] A **detailed explanation of the determination** was provided by energy regulator Ofgem

[46] See Belfast Telegraph (2018) **Cost of keeping Kilroot Power Station open will 'load £14m' on to customers' energy bills**

[47] We currently anticipate that Fiddlers Ferry and Cottam would close by 2020 (as would Uskmouth in order to facilitate its planned conversion), while Aberthaw and West Burton are more likely to take the PLD route (or would need to withdraw from capacity contracts).

[48] See the section **'Knowledge Sharing' on BEIS webpage on CCS**

[49] **BEIS (2018) Government response to unabated coal closure consultation**

[50] **BEIS (2018) UK carbon capture, usage and storage guidance**

[51] See Guardian (2017) **Ban coal from backup power subsidy scheme, says Scottish Power**

[52] **Guardian (2018) Rugeley coal plant to be transformed into a sustainable village**

[53] Note that this section discusses Transmission Entry Capacity figures as reported by DUKES, which reflects the size of the grid connection at each power plant. This is a lower figure than the gross Installed Capacity of the power plant, which we use in Section 4.

[54] See **Carbon Brief (2018) Analysis: UK government slashes outlook for new gas power plants** and **Sandbag (2018) Coal to clean – how the UK phase out coal without a dash for gas**

[55] **Business Green (2018) UK low carbon sectors growing at almost treble the rate of the wider economy**

[56] **CCC (2017) Meeting carbon budgets: closing the policy gap**

[57] The significant investment in Ratcliffe is the exception to this.

[58] This has short term benefits for security of supply but risks blocking new investment from entering the market.

[59] See **Land Regeneration Management case study**

[60] See **Chronicle Live (2017) Plans to turn Blyth Power Station site into jobs hub take major leap forward**

[61] See Guardian (2018) **Rugeley coal plant to be transformed into a sustainable village**

[62] **EU Coal regions in transition platform (2018) Energy storage to the next level: slides** From **Presentations: Coal Regions in Transition Platform Working Groups, 12 to 13 July 2018**

[63] See for example **SSE press release on Ferrybridge**

[64] **Sheffield Hallam University (2017) Coal Transition in the UK**

[65] A useful overview is provided in **House of Commons note on coal plant closures**

[66] See Financial Times (2017) **Coal traffic slump frees space for more passenger trains**

[67] In 2015, the government signalled a desire for new gas generation, but has subsequently significantly revised down its projections of new gas construction.

[68] See impact assessment for consultation **Coal generation in Great Britain: The pathway to a low-carbon future**

[69] **Drax (2018) The roadmap to zero carbon**

[70] For details on these other Drax Group businesses see **Drax: About Us**

[71] Details of the acquisition are available at **Drax (2018) Acquisition of flexible, low-carbon and renewable UK power generation from Iberdrola**

[72] **Simec Atlantis (2017) Proposed Acquisition of SIMEC Uskmouth Power Limited, Creation of a Renewable Energy Platform and Change of Name to SIMEC Atlantis Energy Limited**

[73] **Simec Atlantic (2018) FEED contract awarded for world's first conversion from coal to 100% waste derived fuel**

[74] **Simec Atlantis: Project Development and Operation, Waste to Energy**

[75] GFG Alliance is a $13 billion-turnover industrial group led by Sanjeev Gupta, which has a major stake in SIMEC Atlantis.

[76] **Lynemouth Power (2015) Steps towards conversion**

[77] **Power Technology (2018) Lynemouth Biomass Power Station**