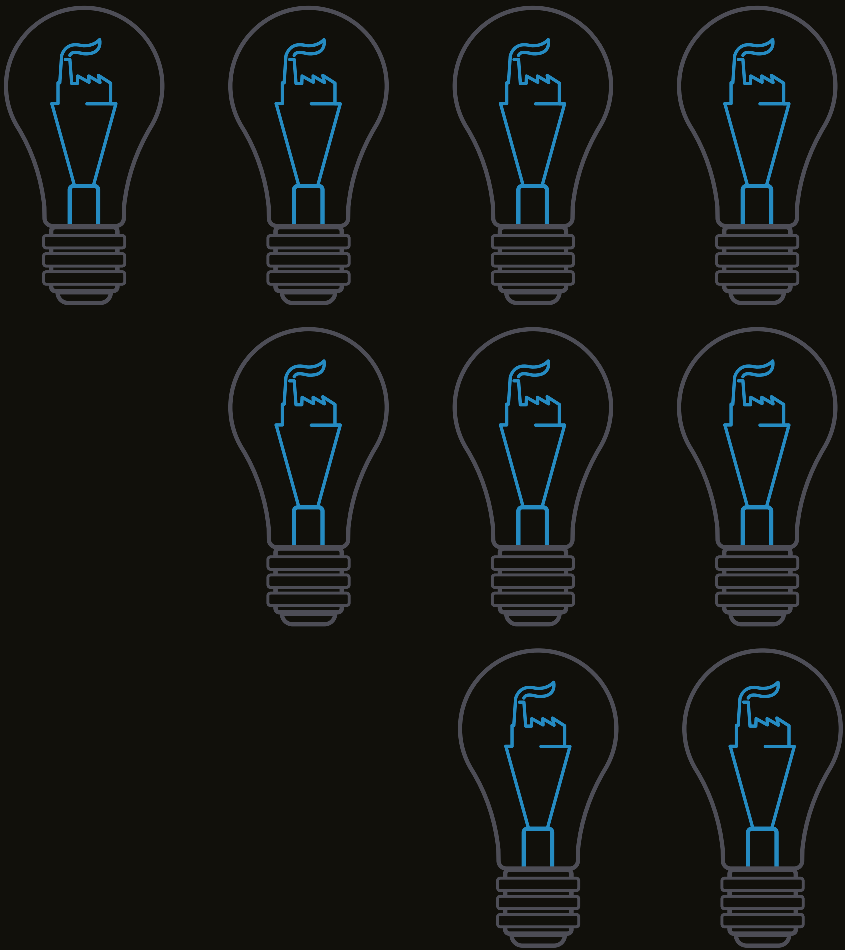

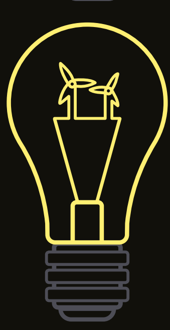

KEEPING THE LIGHTS ON

Security of supply after coal

Ben Caldecott

bright blue

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About the author

Ben Caldecott

Ben is an Associate Fellow at Bright Blue. He is also co-founder of the Conservative Environment Network, Director of the Sustainable Finance Programme at the University of Oxford's Smith School of Enterprise and the Environment, an Adviser to The Prince of Wales's Accounting for Sustainability Project, an Academic Visitor at the Bank of England, and a Visiting Scholar at Stanford University. Ben has a number of board and advisory panel appointments, including with the Green Alliance, Carbon Tracker Initiative, Natural Capital Declaration, and the University of Oxford's Socially Responsible Investment Review Committee.

Prior to moving to the Oxford Smith School he was Head of Policy at investment bank Climate Change Capital, where he ran the company's research centre and advised clients and funds on the development of policy-driven markets. Ben has previously worked as Research Director for Environment and Energy at the think tank Policy Exchange, as Head of Government Advisory at Bloomberg New Energy Finance, as a Deputy Director in the Strategy Directorate of the UK's Department of Energy and Climate Change, and as Sherpa to the UK Green Investment Bank Commission established by George Osborne MP as Shadow Chancellor.

Ben read economics and specialised in development and China at the University of Cambridge and the School of Oriental and African Studies, University of London. He has been a Visiting Scholar at Peking University and held Visiting Fellowships at the University of Oxford and the University of Sydney. Ben is also a Fellow of the Royal Asiatic Society and Royal Geographical Society, a Senior Associate at E3G, and a Member of the Senior Common Room at Oriel College, Oxford.

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The author would like to thank Ryan Shorthouse and Sam Hall at Bright Blue for their feedback, comments and support, as well as Aurora Energy Research, in particular Ben Irons and Harry Granqvist.

Aurora Energy Research was commissioned by Bright Blue to provide an independent perspective on what will be needed to replace coal in the Great Britain electricity generation mix. Aurora Energy Research produced an independent analysis, which is included in the annex to this report.

Executive summary

In our report last year, *Green and responsible conservatism*, we argued that the Government should phase out the UK's remaining coal-fired power stations. A few months later, the Secretary of State for Energy and Climate Change, the Rt Hon Amber Rudd MP, gave a major speech where she announced a commitment to close coal by 2025 and restrict its use from 2023, with the proviso that sufficient gas-fired capacity was available to ensure security of supply. Since that significant declaration, concerns have been raised about the impact of coal closures on security of supply. Could a coal phase-out in the early 2020s result in the lights going out?

Given these concerns, Bright Blue commissioned Aurora Energy Research to develop scenarios to 'stress test' security of supply in light of coal closure plans. Their analysis is included as an annex to this report.

As Chapter One details, three market scenarios were modelled by Aurora:

- **'Base case'.** Renewables, nuclear and interconnector capacities continue to grow largely according to market expectations. Hinkley Point C nuclear power station is delivered in 2029 (three years behind schedule). Coal is forced to close at the end of 2025, but increased procurement under the Capacity Market creates a more favourable environment for all existing thermal plant in the first half of the 2020s, including coal. Overall, there is a moderate need for additional thermal plant in the near term.

- **'Low stress'.** The build-out of renewables, nuclear, and interconnectors exceeds current expectations. This is coupled with falling demand and the build-out of demand side response (DSR) and storage. Hinkley

Point C nuclear power station is delivered in 2026 (on the current schedule). Coal is forced to close at the end of 2025 at the latest, but may choose to close economically even earlier. This creates a less profitable environment for marginal thermal plant and there is very limited need for additional thermal plant over the long term.

- **'High stress'.** Demand rises and the build-out of renewables, nuclear and interconnectors is much slower than expected. Additionally, in order to simulate a pessimistic response to forced closures, all coal plant is assumed to close by the end of 2020. Hinkley Point C nuclear power station is also cancelled. This combination means that this should be seen as the worst case scenario.

Key findings

Each scenario has implications for demands on gas capacity, meeting the UK's emission targets and household bills. This is explored in detail in Chapter Two.

Under all scenarios, the lights stay on. Phasing out coal will not undermine the security of the UK's energy supply. There is plenty of time under each scenario to commission any required new gas capacity. The scenario with the fewest security of supply concerns is very clearly the 'low stress' scenario, where only 8GW of new gas is needed over the next fifteen years. While the 'base case' has large new build requirements for gas in the second half of the 2020s (10GW between 2026 and 2028), very little is required before 2025. The 'high stress' scenario requires 21GW of new gas between 2020 and 2030, which is significant, but manageable given previous UK experience in the 1990s. Even in the 'high stress' scenario, however, no new gas beyond what is already committed is needed between 2016 and 2020.

In terms of carbon emissions, the 'high stress' and 'base case' scenarios both fail to meet the UK's 100gCO_2/kWh target for carbon intensity by 2030, with the 'high stress' scenario exceeding this by 50%. The 'low stress' scenario meets our 2030 targets with time to spare.

In the 'base case', the typical annual household bill (excluding taxes and the retail top-up on wholesale prices) is forecasted to average £241 over the next fifteen years. The 'low stress' scenario is £2.40 below the 'base case', whereas the 'high stress' scenario is £1.20 higher. This an impressively small range given the very different outcomes for gas, coal and decarbonisation. The scenario that is most preferable in terms of security of supply and decarbonisation – the 'low stress' scenario – is also preferable from a cost perspective.

Policy recommendations

Building on the findings from the Aurora report, we make a number of policy recommendations to ensure the success of the phase-out of UK coal:

- The Government should proceed with its coal phase-out plans. There are significant carbon and air pollution benefits of phasing coal out sooner, rather than later. We believe that the 2025 target should be brought forward to at least 2023 to give investors greater certainty, particularly those planning new gas capacity. This can be achieved without threatening security of supply.

- We recommend that the Government use an emissions performance standard to simply regulate coal off the system by the target date. This is by far the simplest method to guarantee policy outcomes and send clear signals to the market.

- There are significant benefits of encouraging the 'low stress' scenario to materialise. It is the lowest cost, the most secure, and by far the least polluting. To deliver this 'low stress' pathway, the Government must encourage renewables and interconnection, as well as storage, DSR and energy efficiency.

- The Government should develop targets and plans for DSR and storage, aiming for 4–5GW and 5–6GW of capacity respectively by 2030. This is aligned with the 'low stress' scenario. It should also develop plans to encourage the deployment of smaller scale flexible gas capacity, such as reciprocating gas engines, which can contribute to managing intermittency more effectively than Combined Cycle Gas Turbines (CCGTs).

- Domestic energy efficiency is in a state of flux, particularly in the able to pay domestic sector due to the failure of the Green Deal. Bright Blue will soon be publishing a new report as part of its *Green* *conservatism* project, making specific policy recommendations for the Government to turn this around, by creating a new home improvement mechanism. This is needed to ensure that energy demand continues its recent downward trend.

- The future of Hinkley Point C nuclear power station appears to be highly uncertain. Should the project not materialise, renewables can easily fill the capacity gap in the late 2020s. This should be 'Plan B'. From 2011 to 2015 the share of renewables in total UK electricity generation leaped from 9% to 25%. Costs are now even lower and the technologies achieving maturity and cost competitiveness without subsidy. For example, the costs of solar photovoltaic (PV) and onshore wind have fallen by 50% and 43% respectively since 2011. Renewables can, therefore, plug significant gaps in capacity very quickly – much more quickly than long lead time and significantly delayed new nuclear. The ability of these technologies to deliver this capacity is already impressive and will be even more so in the mid to late 2020s. In contrast, we believe that proposed small modular nuclear reactors are very unlikely to be available at all, let alone before the 2030s in any scalable, cost-competitive or politically acceptable way.

- The UK should build on its coal policy by taking the lead in promoting coal phase-out internationally. Globally, coal needs to be dismantled to tackle climate change and the UK has significant technical and moral leadership it can deploy to encourage other countries to agree to a coordinated phased approach for closing down coal-fired power stations. The world's climate future really does hinge on what other countries do with their coal fleets.

Conclusion

Committing to the phase-out of UK coal-fired power stations is a radical and ambitious conservative approach to dealing with climate change and air pollution. It has supported an ambitious outcome at the Paris climate change negotiations in December 2015 and has been welcomed with widespread acclaim in the UK and internationally. The Government should be praised for its leadership.

Coal phase-out, even under a 'high stress' scenario, will not result in the lights going out. The analysis presented in this report also shows the significant benefits for pollution, energy bills, and system security of pursuing a 'low stress' scenario, by further encouraging renewables, interconnection, storage, DSR, and energy efficiency.

Chapter 1: **Introduction**

In Bright Blue's report *Green and responsible conservatism*, published last summer,[1] we argued that the Government should announce an ambitious plan to phase out the UK's remaining coal-fired power stations.

There is a compelling case to phase out coal given its disproportionate contribution to UK power sector emissions (76% as recently as 2013)[2] and given that it generates air pollution estimated to cost the NHS up to £3.1 billion per year.[3] It is also one of the most cost-effective ways of tackling climate change as our remaining coal-fired power stations are well over forty years old and fully depreciated.

We also argued that as the first country to use coal for electricity (since 1882), the UK announcing its intention to become the first major economy to phase it out would inject important momentum for phasing out coal internationally.

In November 2015, the Secretary of State for Energy and Climate Change, the Rt Hon Amber Rudd MP, gave a major speech that endorsed our proposals. The centerpiece of this was a commitment to close coal by 2025 and restrict its use from 2023, with the proviso that sufficient gas-fired capacity was available to ensure security of supply. We warmly welcomed the announcement, together with an incredibly diverse range of respected organisations and individuals in the UK and internationally.

1 Ben Caldecott, *Green and responsible conservatism* (London: Bright Blue, 2015).

2 National Atmospheric Emissions Inventory, "UK greenhouse gas inventory", https://uk-air.defra.gov.uk/assets/documents/reports/cat07/DA_GHGI_1990-2013_Report_v1.pdf (2015).

3 HEAL, "The unpaid health bill: how coal power plants make us sick", www.env-health.org/IMG/pdf/heal_report_the_unpaid_health_bill_-_how_coal_power_plants_make_us_sick_finalpdf.pdf (2013).

Since that declaration, concerns have been raised about the impact of coal closures on security of supply. Could a coal phase-out in the early 2020s result in the lights going out?

The UK's coal generation capacity in 2012 was 28GW[4] but since then approximately 13 GW of this capacity has already closed, leaving the UK with just ten coal-fired power stations with 15GW of capacity.[5] This rapid fall in coal capacity has not resulted in the lights going out. Several times in May 2016, for the first time since 1882, coal was not contributing any electricity to the UK grid.[6] One of the reasons for this has been the surprisingly large growth in renewables from 9% in 2011 to 25% in 2015.[7] This demonstrates how quickly things can change and that such changes have so far been successfully managed.

In light of continued concerns, especially as we look beyond 2020, we decided to commission further research. We commissioned Aurora Energy Research to develop scenarios to 'stress test' security of supply in light of coal closure plans. Their analysis would help us to answer the following three key research questions:

1. What types of capacity could replace the coal fleet as it closes?
2. How might coal replacement vary due to other uncertainties around demand, renewables, new nuclear and interconnection?
3. What is required to ensure adequate security of supply as the coal fleet is forced to close in the early 2020s?

Three market scenarios were modelled by Aurora to capture the plausible range of new build that would ensure security of supply. A full description of the scenarios can be found in their independent report, which is published as an annex to this report. The scenarios are described briefly below:

4 DECC, "Coal in 2012", www.gov.uk/government/uploads/system/uploads/attachment_data/file/170708/et_article_coal_in_2012.pdf (2012).

5 Simon Evans, "Countdown to 2025: tracking the UK coal phase out", *Carbon Brief*, 10 February 2016.

6 Press Association, "UK energy from coal hits zero for first time in 100 years", *The Guardian*, 13 May 2016.

7 DECC, "Energy trends March 2016", www.gov.uk/government/uploads/system/uploads/attachment_data/file/511931/Electricity.pdf (2016).

- **'Base case'.** Renewables, nuclear, and interconnector capacities continue to grow largely according to market expectations. Hinkley Point C nuclear power station is delivered in 2029 (three years behind schedule). Coal is forced to close at the end of 2025, but increased procurement under the Capacity Market creates a more favourable environment for all existing thermal plant in the first half of the 2020s, including coal.[8] Overall there is a moderate need for additional thermal plant in the near term.

- **'Low stress'.** The build-out of renewables, nuclear and interconnectors exceeds current expectations. This is coupled with falling demand and the build-out of demand side response (DSR) and storage. Hinkley Point C nuclear power station is delivered in 2026 (on the current schedule). Coal is forced to close at the end of 2025 at the latest, but may choose to close economically even earlier. This creates a less profitable environment for marginal thermal plant and there is very limited need for additional thermal plant over the long term.

- **'High stress'.** Demand rises and the build-out of renewables, nuclear and interconnectors is much slower than expected. Additionally, in order to simulate a pessimistic response to forced closures, all coal plant is assumed to close by the end of 2020. Hinkley Point C nuclear power station is also cancelled. This combination means that this should be seen as the worst case scenario.

The underlying assumptions for each scenario can be found in the accompanying annex of this report.

The next chapter summarises the key findings from Aurora's analysis and suggests new policy recommendations to ensure the successful phase-out of coal from the UK.

8 This assumes no restrictions on coal's participation in capacity auctions, which has been the case to date.

Chapter 2: Key findings and policy recommendations

The previous chapter described the motivations for and outline of Aurora's analysis (see annex), presenting three scenarios for the phase-out of coal-fired power stations on the UK's energy supply. This chapter outlines the implications of each scenario for demands on gas capacity, meeting the UK's emission targets and household bills. Finally, it suggests new policies to ensure the successful phase-out of UK coal.

'Base case' scenario

As Chart 1.1 in the annex illustrates, total coal capacity is stable at just over 7GW throughout the first half of the 2020s. The proposed higher capacity market procurement is a key factor in keeping capacity prices high enough to keep coal on the system, at the expense of marginal Combined Cycle Gas Turbines (CCGTs) and new build.

With coal remaining operational until 2025, very little additional gas plant beyond what has already been procured is required. Once coal exits, however, significant new build is needed to fill the gap, with nearly 10GW of CCGT being built between 2026 and 2028. This is shown in Charts 1.2 and 1.3 in the annex.

Load factors for both CCGT and coal fall in the next five years as renewables output increases. In the early 2020s retirements of marginal CCGTs will allow remaining coal plant to increase production before being forced to close by 2025, putting coal's share of total generation over the next ten years at 7%.

As indicated in Chart 1.8 in the annex, the average carbon intensity of domestic generation falls steadily in the next five years as renewables output increases and several coal plants close. However, in the first half of the 2020s, increased generation by remaining coal plant fills the gap left by retiring CCGTs, and the CO_2 intensity of the system as a whole increases in the 2021 to 2025 period. Only when 7GW of coal plant retires at the end of 2025 does the CO_2 intensity start falling again. The system CO_2 intensity approaches the 100gCO_2/kWh target in the late 2020s, but the target is not met.

In the 'base case', the typical annual household bill (excluding taxes and the retail top-up on wholesale prices) is forecasted to average £241 over the next fifteen years. Of this total, £153 is attributable to electricity costs, £8 to capacity market costs, and the remaining £79 to other policy costs.

'Low stress' scenario

As the annex details, coal is forced to close at the end of 2025 at the latest, but may choose to close economically even earlier. When coal does close, it only serves to momentarily halt the decline in CCGT output, which then continues to fall as CCGTs are squeezed out by renewables, nuclear and interconnectors.

Total coal capacity falls below 2GW by the end of 2020, as very few coal plants find it economical to opt in to the Industrial Emissions Directive (IED) and operate beyond that point. Lower capacity market prices and fewer running hours for coal means that most coal plants bid high and lose the capacity auction and retire around 2021, even though they are free to run to 2025. This is illustrated by Chart 1.1 in the annex.

Only about 8GW new gas plant will be needed in the next 15 years, in addition to what has already been procured (see Charts 1.2 and 1.3 in the annex). However, with a larger share of intermittent renewables on the system, less of this new gas capacity needs to be large-scale CCGT, and more needs to be small-scale, more flexible plant.

Total CO_2 intensity falls steadily in the 2016 to 2020 period (see Chart 1.8 in the annex). This decline continues uninterrupted into the 2020s. A combination of lower demand, higher output from renewables and more interconnection allow for adequate generation without coal or lots more gas. At this steady rate of decline, the 100gCO_2/kWh target CO_2 intensity for 2030 is met in the mid 2020s.

The typical annual household bill is approximately £2.40 lower than in the 'base case'. The total cost of Contracts for Difference (CfD), Renewables Obligation Certificates (ROC), and Feed-in-Tariffs (FIT) is higher due to the higher installed renewables capacity, but not so much as to offset the reduction in electricity and capacity prices.

'High stress' scenario

One of the key findings of this report is that even in the 'high stress' scenario – where coal closes by the end of 2020, non-fossil capacity grows less than expected, and energy demand increases – the immediate need for new build gas is surprisingly low. Much lower than others have suggested.[9] Beyond what is already committed, no additional gas is required between 2016 and 2020. Life extensions and increased utilisation of existing CCGTs make up for 46% of the lost generation from coal (see Charts 1.4 and 1.5 in the annex). The greater utilisation of existing gas assets is a key factor in curbing the need for new-build gas plants.

From 2020 to 2025, approximately 10GW of new-build gas will be needed (see Charts 1.2 and 1.3 in the annex). For context, it takes two to three years to build a CCGT once permissions have been acquired[10] and currently 19GW[11] are in the planning system or under construction.

In the second half of the 2020s, another 11GW of new gas plant will be needed in order to cope with gas plant retirements, high demand, stagnating renewables build-out and a slump in nuclear capacity. This level of gas build, 21GW from 2020 to 2030, looks manageable based on previous UK experience. For example, during the 'dash-for-gas' in the late 1990s, there were years in which the amount of new build CCGT exceeded 3GW per year.[12]

9 Institute of Mechanical Engineers, "Engineering the UK electricity gap", www.imeche.org/docs/default-source/position-statements-energy/imeche-ps-electricity-gap.pdf?sfvrsn=0, 2016; Tony Lodge, *Great Green Hangover* (London: Centre for Policy Studies, 2015); Liberum Capital' in Emily Gosden, 'New gas plants "to be shelved after failing to win subsidies" ', *Daily Telegraph*, 18 December 2014.

10 Parsons Brinckerhoff, "Coal and gas assumptions", www.gov.uk/government/uploads/system/uploads/attachment_data/file/315717/coal_and_gas_assumptions.pdf (2014), 19.

11 Friends of the Earth, "The return of the dash for gas", www.foe.co.uk/sites/default/files/downloads/return-dash-gas-77109.pdf, 2015; DECC, "Energy infrastructure: recent decisions on applications", www.og.decc.gov.uk/EIP/pages/recent.htm, 2015.

12 Parsons Birckenhoff, "Coal and gas assumptions", 12.

So while there is no immediate security of supply challenge in the 'high stress' scenario, this scenario does require significant, albeit manageable, new gas build post-2020. One significant downside of this is that it results in the 100gCO_2/kWh target intensity by 2030 not being met and it being exceeded by more than 50% (see Chart 1.8 in the annex). This has significant implications for the UK's carbon budgets. The reason why the target is not met is that the stagnating build-out of zero-carbon generation capacity as well as interconnection, means that the CCGT fleet must both grow and increase production up to 2030, completely halting and even reversing the decline in CO_2 intensity in the mid-2020s due to coal closure.

In the 'high stress' scenario, the typical annual household bill (excluding taxes and the retail top-up on wholesale prices) is approximately £1.20 higher than in the 'base case'. The total CfD, ROC and FIT costs are lower due to lower renewables capacity, but not so much as to offset the increase in electricity and capacity prices. It should be noted that the greater dependency on gas and gas imports in this scenario makes the household bill estimates particularly sensitive to the price of gas, particularly Liquefied Natural Gas (LNG).

The implications of phasing out coal

Under all scenarios from Aurora's analysis, the lights stay on. Phasing out coal will not undermine the security of the UK's energy supply. There is plenty of time under each scenario to commission any required new gas capacity. The scenario with the fewest security of supply concerns is very clearly the 'low stress' scenario, where only 8GW of new gas is needed over the next fifteen years.

While the 'base case' has large new build requirements for gas in the second half of the 2020s (10GW between 2026 and 2028), very little is required before 2025. The 'high stress' scenario requires 21GW of new gas between 2020 and 2030, which is significant, but manageable given previous UK experience in the 1990s. Even in the 'high stress' scenario, however, no new gas beyond what is already committed is needed between 2016 and 2020.

In terms of carbon emissions, the 'high stress' and 'base case' scenarios both fail to meet the 100gCO_2/kWh intensity target by 2030, with the 'high stress' scenario exceeding this by 50%. The 'low stress' scenario meets our 2030 target with time to spare.

In the 'base case', the typical annual household bill (excluding taxes and the retail top-up on wholesale prices) is forecasted to average £241 over the next fifteen years. The typical annual household bill under the 'low stress' scenario is £2.40 below the 'base case', whereas the 'high stress' scenario is £1.20 higher. This is an impressively small range given the very different outcomes for gas, coal and decarbonisation. The scenario that is most preferable in terms of security of supply and decarbonisation – the 'low stress' scenario – is also preferable from a cost perspective.

One of the striking things about each of the three scenarios is how successful renewables deployment has been and will continue to be due to falling costs and economies of scale. Across the scenarios the amount of installed solar capacity ranges from 12.5GW to 17.44GW by 2025 (it is currently 8.9GW), onshore wind from 12.9GW to 15.9GW (it is currently 9.1GW) and offshore wind from 11.3GW to 14.4GW (it is currently 5.1GW).[13] The growth in renewables over the last few years, from 9% of total annual UK electricity production in 2011 to 25% in 2015 demonstrates the role these technologies can play in a very short period of time.[14] According to the scenarios, renewables is set to account for between 34% and 38% of cumulative electricity production by between 2016 and 2025 (see Chart 1.6 in the annex). Even as subsidies are reduced and eliminated, the growth of renewables seems likely to continue as costs fall and they become ever more competitive without subsidy.

Key uncertainties are the availability and cost of electricity storage and the deployment of electric vehicles. The former will help manage intermittency from renewables and reduce the need for new gas capacity. While the latter could increase the demand for electricity, it could also provide grid storage capacity. Electric vehicle deployment would also reduce the amount of air pollution from petrol and diesel cars, which is an important alignment with climate change policy and required to reduce urban air pollution. Another uncertainty, particularly for household bills and energy security, is growing gas import dependency under both the 'high stress' scenario and 'base case'.

13 DECC, "Energy trends March 2016", www.gov.uk/government/uploads/system/uploads/attachment_data/file/517573/Energy_Trends_March_2016.pdf, (2016) 51.

14 DECC, "Energy trends March 2012", www.gov.uk/government/uploads/system/uploads/attachment_data/file/65909/4779-energy-trends-mar12.pdf, (2012) 45.

Policy recommendations

Building on the findings from the Aurora report in Chapter Two, we make a number of policy recommendations to ensure the success of the phase-out of UK coal:

- The Government should proceed with its coal phase-out plans. There are significant carbon and air pollution benefits of phasing coal out sooner, rather than later. We believe that the 2025 target should be brought forward to at least 2023 to give investors greater certainty, particularly those planning new gas capacity. This can be achieved without threatening security of supply.

- We recommend that the Government use an emissions performance standard to simply regulate coal off the system by the target date. This is by far the simplest method to guarantee policy outcomes and send clear signals to the market.

- There are significant benefits of encouraging the 'low stress' scenario to materialise. It is the lowest cost, the most secure, and by far the least polluting. To deliver this 'low stress' pathway, the Government must encourage renewables and interconnection, as well as storage, DSR and energy efficiency.

- The Government should develop targets and plans for DSR and storage, aiming for 4–5GW and 5–6GW of capacity respectively by 2030. This is aligned with the 'low stress' scenario. It should also develop plans to encourage the deployment of smaller scale flexible gas capacity, such as reciprocating gas engines, which can contribute to managing intermittency more effectively than CCGTs.

- Domestic energy efficiency is in a state of flux, particularly in the able to pay domestic sector due to the failure of the Green Deal. We will soon be publishing a new report as part of our *Green conservatism* project, making specific policy recommendations for the Government to turn this around, by creating a new home improvement mechanism. This is needed to ensure that energy demand continues its recent downward trend.

- The future of Hinkley Point C nuclear power station appears to be highly uncertain. Should the project not materialise, renewables can easily fill the capacity gap in the late 2020s. This should be 'Plan B'. From 2011 to 2015 the share of renewables in total UK electricity generation leaped from 9% to 25%. Costs are now even lower and the technologies achieving maturity and cost competitiveness without subsidy. For example, the costs of solar PV and onshore wind have fallen by 50% and 44% respectively since 2011.[15] Renewables can, therefore, plug significant gaps in capacity very quickly – much more quickly than long lead time and significantly delayed new nuclear. The ability of these technologies to deliver this capacity is already impressive and will be even more so in the mid to late 2020s. In contrast, we believe that proposed small modular nuclear reactors are very unlikely to be available at all, let alone before the 2030s in any scalable, cost-competitive or politically acceptable way.

- The UK should build on its coal policy by taking the lead in promoting coal phase-out internationally. Globally, coal needs to be dismantled to tackle climate change and the UK has significant technical and moral leadership it can deploy to encourage other countries to agree to a coordinated phased approach for closing down coal-fired power stations. The world's climate future really does hinge on what other countries do with their coal fleets.

Conclusion

There is a significant political legacy of the UK being the first industrialised country and first to use coal for electricity to be the first major country to completely phase it out. It is a radical and ambitious conservative approach to dealing with climate change and air pollution. Closing coal is also a cheap and rational way of reducing carbon emissions.

15 DECC, "Electricity generation costs", www.gov.uk/government/uploads/system/uploads/attachment_data/file/65713/6883-electricity-generation-costs.pdf, 2012; REA, "UK solar beyond subsidy: the transition", www.r-e-a.net/upload/uk-solar-beyond-subsidy-the-transition.pdf, 2015; Bloomberg New Energy Finance, "Wind and solar boost cost-competitiveness versus fossil fuels", about.bnef.com/press-releases/wind-solar-boost-cost-competitiveness-versus-fossil-fuels/, 2015.

The policy has already supported an ambitious outcome at the Paris climate change negotiations in December 2015 and has been welcomed with widespread acclaim in the UK and internationally. The key is now for the Government to properly follow through.

Coal phase-out, even under a 'high stress' scenario, will not result in the lights going out. Bringing forward the 2025 target date to 2023 would actually provide more certainty for investors in new gas, improving energy security. Moreover, the analysis presented here has shown the significant benefits for pollution, energy bills, and system security of pursuing a 'low stress' scenario, by further encouraging renewables, interconnection, storage, DSR, and energy efficiency.

Annex: An assessment of GB security of supply and new build gas requirements to 2030

Foreword

Aurora Energy Research ('Aurora') has been commissioned by Bright Blue to provide an independent perspective on what will be needed to replace coal in the Great Britain ('GB') electricity generation mix if the proposed phase-out of coal in the 2020s becomes policy. This report reflects Aurora's independent perspective as a leading energy market modelling and analytics company. While our clients have separately provided their own assessment of the implications of our analysis, the analysis itself is Aurora's own, independent and based on our modelling capabilities and judgment of the relevant uncertainties. The views expressed by Bright Blue do not necessarily reflect or represent those of Aurora.

The analysis done for this report is underpinned by the Aurora Energy Research Electricity System model for Great Britain ('AER-ES GB'). It is a market-leading dispatch model used by many of the major private and public sector organisations to address questions across strategy, policy and finance.

Context and objectives of this report

On 18 November, 2015, the Secretary of State for Energy and Climate, the Rt Hon Amber Rudd MP, announced that the Government intended to 'reset' national energy policy in the UK, to address concerns about energy security and decarbonisation.[16] This 'reset' involved launching a policy consultation in the spring of 2016, which would include a proposal to close all coal-fired generation capacity by 2025, and restrict its use from 2023. A caveat to the stated ambition to phase

16 Amber Rudd, *A new direction for UK energy policy*, 18 November 2015, https://www.gov.uk/government/speeches/amber-rudds-speech-on-a-new-direction-for-uk-energy-policy.

out coal, however, was that it would only be done if there could be sufficient assurance that a shift from coal to gas would be manageable within this timeframe. The overriding emphasis in Amber Rudd's speech was on energy security as 'the number one priority', which means that enough generation capacity – gas-fired as well as other types – must be built to guarantee adequate system reliability as 12 gigawatts ('GW') of coal plant leaves the system in the 2016–2025 period.

This report documents Aurora's assessment of the extent and the timing of the shift to gas that will be needed to provide adequate security of supply in a number of scenarios where coal leaves the system in the 2020s. We deployed our market-leading electricity dispatch model for the GB electricity market to address three key questions:

- What combination of new gas plant and other types of generating capacity will be needed to replace the coal fleet when and if it closes?
- What will allow the lights to stay on if the coal fleet is forced to close in the 2020s?
- How might this vary due to other uncertainties around demand, renewables, new nuclear, and interconnection?

Scenario descriptions

While coal is expected to provide more than 10% of total electricity consumed in GB in the next couple of years, its role in the overall generation mix in the 2020s is more uncertain. For this reason, the amount of stress to the system that forcing coal to close will cause is also uncertain, as is the response of British coal plants to such a policy. Coal, like gas, competes against low-marginal-cost generation sources like nuclear and renewables, and has in recent years seen its share of total generation fall by more than half. Renewables capacities will continue to grow in the next 15 years, but at what rate is highly uncertain. Additionally, developments in energy efficiency and electric vehicles could dramatically affect the amount of electricity that needs to be generated in any given year. The key forecasting challenge for decision-makers is therefore how much coal- and gas-fired generation will be needed to close the gap between electricity demand and other types of generation in the 2020s.

Aurora's modelling approach is well suited for this type of forecasting. The Aurora Energy Research Electricity System model for Great Britain ('AER-ES GB') optimises the dispatch behaviour of all generation types over time, given policy and market conditions, and predicts the amount of new-build generation capacity that will ensure security of supply in each year. Inherent in Aurora's approach is an understanding of the reliability of the generation fleet, including renewables, optimal dispatch profiles, and the economically rational entry and exit of generation capacity in response to market signals. We assume that the capacity market delivers enough capacity to meet the agreed reliability standard (three hours Loss of Load Expectation in the first two T-4 capacity auctions), but that price signals determine what technologies enter and exit, and when.

Having identified the key uncertainties that are going to affect the total need for thermal generation, AER-ES GB can be deployed to estimate the upper and the lower bounds on how large the gap left by coal will be, and therefore on how much new-build gas is needed to replace it.[17] These uncertainties include the build-out of interconnection and non-fossil generation capacities, electricity demand, as well as other types of policy and how coal plant will react to them.

For this report, Aurora has constructed three market scenarios that address these uncertainties and collectively capture the plausible range of new build quantities that would ensure security of supply in this timeframe. They are as follows:

- **'Base case'.** Moderate need for additional thermal plant in the near term, as renewables, nuclear and interconnector capacities continue to grow largely according to expectations. Although coal is forced to close at the end of 2025, increased procurement under the Capacity Market creates a more favourable environment for all existing thermal plant in the first half of the 2020s, including coal.

- **'Low stress'.** Very limited need for additional thermal plant over the long term, as build-out of renewables, nuclear and interconnectors exceeds current expectations. Coupled with stagnating demand and rapid build-out of demand side response (DSR) and storage, this creates a less profitable environment for marginal thermal plant. Coal is forced to close at the end of 2025 at the latest, but may choose to close economically even earlier.

17 'Thermal generation' generally refers to all fossil-fuelled generation, as well as nuclear.

- **'High stress'.** Great need for more thermal generation as demand rises but build-out of renewables, nuclear and interconnectors is slow. Additionally, in order to simulate a pessimistic response to forced closures, all coal plant is assumed to close already at the end of 2020, increasing the need for new-build gas to provide the necessary security of supply.

Results

Coal plant behaviour

A policy to force coal to close no later than at the end of 2025 is in reality no guarantee that the coal fleet will indeed remain operational for that long. For an individual coal plant, it may be an economically rational response to such a policy to close much earlier. Aurora's modelling has captured the possible range of coal retirement profiles.

In the 'base case', we see that it remains profitable for all Industrial Emissions Directive (IED) opt-in coal plants to remain operational until 2025, at load factors typically in the 30–50% range. As illustrated in Chart 1.1, total coal capacity is stable at just over 7GW throughout the first half of the 2020s. The proposed higher capacity market procurement is a key factor in keeping capacity prices high enough to keep coal on the system, at the expense of marginal Combined Cycle Gas Turbines (CCGTs) and new build.

In the 'low stress' scenario, total coal capacity falls below 2GW already at the end of 2020, as very few coal plants find it economical to operate beyond that. Lower capacity market prices and fewer running hours for coal means that most coal plants bid high and lose the capacity auction and retire around 2021, even though they are free to run to 2025.

In the 'high stress' scenario, all 7GW of coal plant that remain operational in 'base case' close already at the end of 2020. Despite a favourable market outlook for coal in the first half of the 2020s, all coal plants are in this scenario assumed to close after 2020. In reality, this could be a result either of policy or increased pessimism and uncertainty around the outlook for coal, as the favourable market outlook may be unforeseen in 2020.

Table 1.1. Summary of the assumptions that underpin each of the scenarios

	Official target	'Base case'	'Low system stress'	'High system stress'
Coal closure policy	End of 2025 (proposed)	End of 2025	End of 2025	End of 2020
Coal IED opt-ins	N/A	Four plants with option to opt in: Aberthaw, Cottam, Drax, Ratcliffe		
Power demand	N/A	FES[18] 2015 'Consumer power'	-5% relative to 'base case' from 2021	+5% relative to 'base case' from 2021
Offshore wind	13.5 GW by 2026[19]	12.2 GW by 2025	14.4 GW by 2025	11.3 GW by 2025
Onshore wind	13.2 GW by 2020[20]	13.2 GW by 2025	15.9 GW by 2025	12.9 GW by 2025
Solar	12.8 GW by 2020[21]	15.5 GW by 2025	17.4 GW by 2025	12.5 GW by 2025
Interconnection	12.8 GW by 2025[22]	10.8 GW by 2025	12.2 GW by 2025	8.4 GW by 2025
Nuclear	12.4 GW by 2030 (with official new-build commissioning dates)	11.9 GW by 2030	11.9 GW by 2030	8.5 GW by 2030
Hinkley C	2026 delivery	2029 delivery	2026 delivery	Cancelled
DSR	N/A	2.0 GW by 2030	4.5 GW by 2030	1.0 GW by 2030
Grid storage	N/A	5.6 GW by 2030	5.6 GW by 2030	2.7 GW by 2030
Reliability standard	2hrs Loss of Load Expectation (LOLE)[23]	2hrs Loss of Load Expectation (LOLE)	3hrs Loss of Load Expectation (LOLE)	2hrs Loss of Load Expectation (LOLE)
Capacity Market design	Reform happens: annual procurement +1GW (proposed)	Reform happens: annual procurement +1GW	No reform	Reform happens: annual procurement +1GW
Fuel prices	N/A	Forward curves blended into Aurora fundamentals forecast. Gas price rises from 35p/therm to 53p/therm and coal price from £27/tonne to £40/tonne in 2016–2040		
Carbon price	N/A	Freeze in the carbon price floor until 2019/20, after which the carbon price rises from £22/tonne in 2020 to £40/tonne in 2040		
Everything else	N/A	As per Aurora's GB power market forecast (Jan 2016)		

18 National Grid, *Future energy scenarios 2015* (Warwick: National Grid, 2015).

19 *Budget 2016* announced support for up to 4 GW of offshore wind and other less established renewables from 2020–2026; GB offshore wind industry has signalled ability to deliver 3.5 GW. See HM Treasury, *Budget 2016* (London: HM Treasury, 2016).

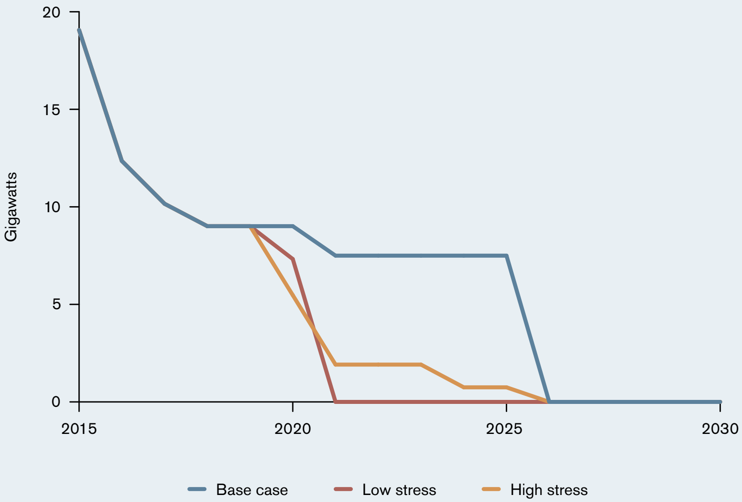
20 Based on DECC estimates after cost control measures, no further guidance available; DECC, *Review of the feed-in tariffs scheme: government response* (London: DECC, 2015).

21 Based on DECC estimates after cost control measures, no further guidance available; ibid.

22 *Budget 2016* announced ambition for 9 GW of additional interconnection, above 3.8 GW current capacity.

23 Implied by the proposed increase in the Capacity Market procurement target.

Chart 1.1. Operational coal-fired generation capacity, 2015–2030



New-build gas plant

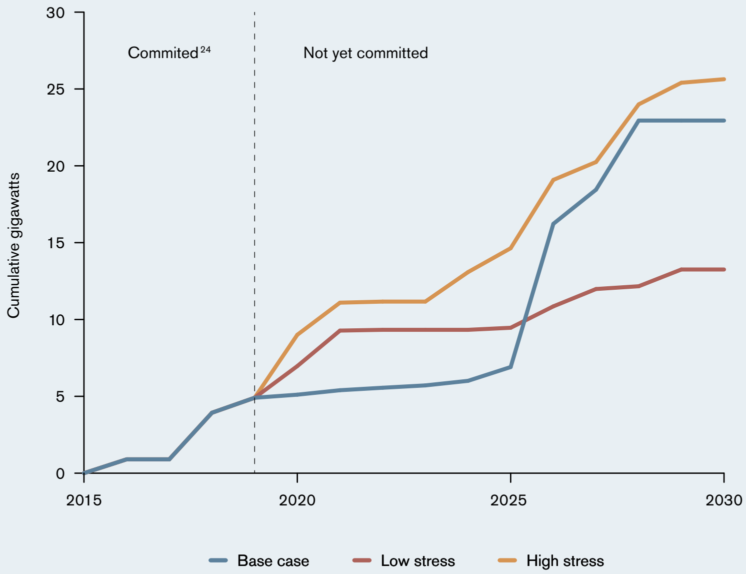
As coal leaves the system, Aurora's modelling predicts how much new build gas is needed to meet security of supply targets, given other market factors such as demand and build-out of other technologies.

In the 'base case', the 2025 coal closure policy has very little effect on new build requirements in the next ten years. With coal remaining operational until 2025, very little additional gas plant beyond what has already been procured through the first two T-4 capacity auctions is needed before 2025. Once coal exits, however, significant new build is needed to fill the gap, with nearly 10GW of CCGT being built in 2026–2028, as illustrated in Charts 1.2 and 1.3. Aurora's modelling places no feasibility constraints on how much capacity can be built in any given year. However, during the 'dash-for-gas' in the late 1990s, there were years in which the amount of new build CCGT exceeded 3GW per year, which is a build rate that would allow for the necessary capacity additions also in the 2020s.

In the 'low stress' scenario, only about 3.5GW new CCGT will be needed in the next fifteen years, in addition to what has already been procured. However, with coal exiting earlier than in 'base case', relatively more of this needs to be built already around 2020. Moreover, with a larger share of intermittent renewables on the system, less of this new gas capacity needs to be large-scale CCGT, and more needs to be small-scale, flexible generators.

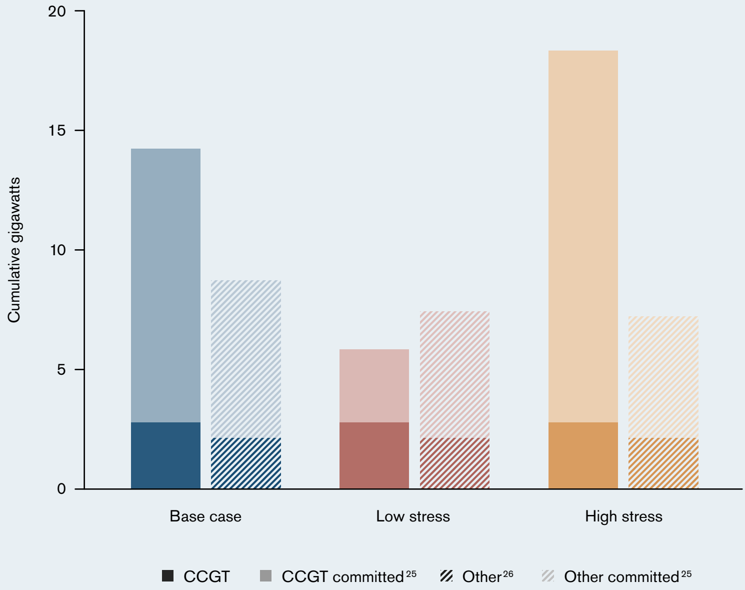
In the 'high stress' scenario, just like in the 'base case' and the 'low stress' scenario, significant new build is needed when coal exits the system, which occurs in 2020. Between 2021 and 2025, however, little additional build is needed as life extensions and increased utilisation of existing CCGTs is sufficient to meet the reliability standard during this period. Only 6GW of new-build gas will be needed in the 2016–2025 period, in addition to what has already been procured. In contrast, the latter half of the 2020s will require very large quantities of new build gas in order to cope with gas plant retirements, high demand, stagnating renewables build-out and a slump in nuclear capacity.

Chart 1.2. Total new-build gas capacity, 2015–2030



24 'Committed' refers to capacity that has already been procured through the first two T-4 capacity auctions, namely 2.8GW of CCGT and over 2GW of small-scale gas capacity.

Chart 1.3. Total new-build gas capacity, 2015–2030



Existing gas plant

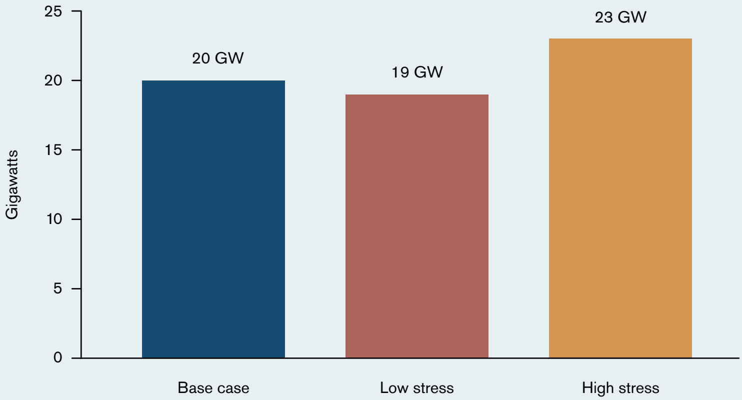
With less coal-fired generation capacity on the system, more electricity needs to come from other sources. New-build gas plant is one of these sources, but so is existing gas-fired capacity. Both life extensions and increased utilisation of existing gas plant can help fill the gap after coal.

In the 'base case', only about 5GW of currently operational CCGT will retire in the 2016–2025 period, meaning that 20GW will remain operational in 2025, as illustrated in Charts 1.4 and 1.5. Despite average load factors dropping by 20% during this period, this is enough to eliminate any need for additional new-build CCGT in the next ten years.

25 'Committed' refers to capacity that has already been procured through the first two T-4 capacity auctions, namely 2.8GW of CCGT and over 2GW of small-scale gas capacity.

26 'Other' refers to Open Cycle Gas Turbine (OCGT) and small-scale reciprocating gas engines.

Chart 1.4. Existing CCGT capacity operational in 2025



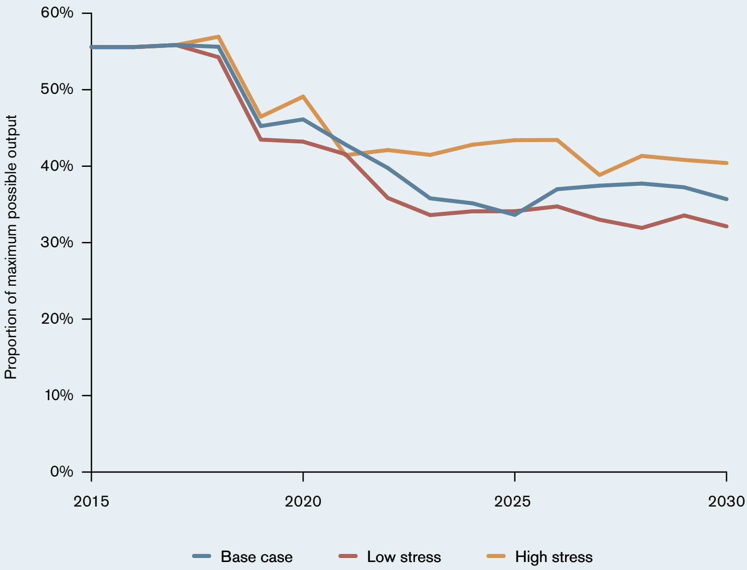
In the 'low stress' scenario, where the need for thermal generation is lower than in 'base case', 1GW more existing CCGT retires before 2025. Mean load factors for the fleet of existing CCGT is on average 2% lower over the horizon as production from renewables and nuclear increases.

In the 'high stress' scenario, life extensions and increased utilisation of existing CCGT is a key factor in curbing the need for new-build gas plant relative to the 'base case'. Only 2GW of CCGT will retire in the next ten years, compared to 5GW in the 'base case', and average load factors in the 2020s will be 4% higher. Existing CCGTs will make up for 46% of the lost generation from coal in the 2021–2025 period.

Electricity production

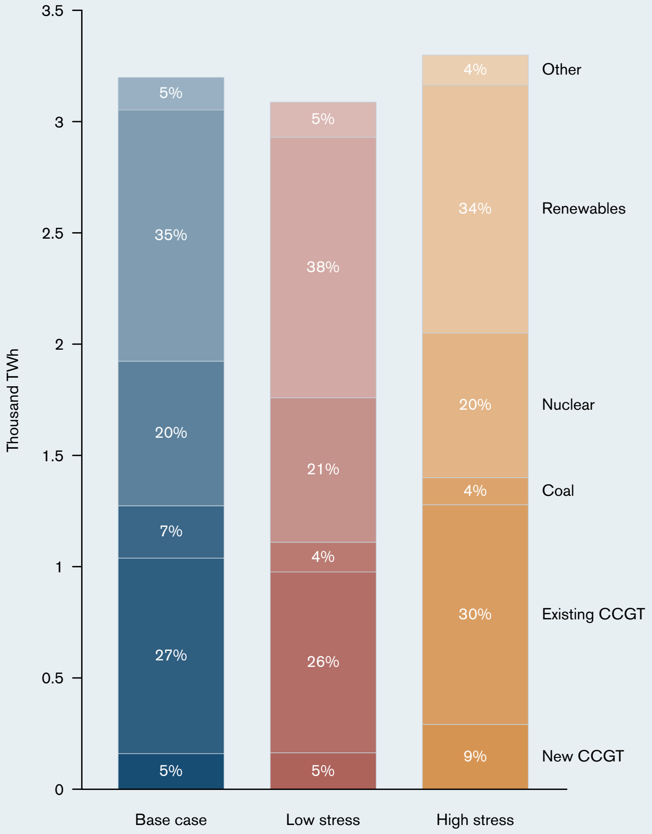
Replacing coal in the generation mix can be achieved either by increasing the utilisation of existing generation capacity or by building new capacity. Charts 1.1 and 1.2 illustrate that when the bulk of coal leaves the system, the amount of new gas that comes in to replace it immediately after is actually smaller, in GW terms. This is partly because 1GW of new gas plant will typically produce much more electricity in one year than 1GW of old coal plant, and partly because existing gas plant will increase production in response to the retirement of coal.

Chart 1.5. Utilisation of existing CCGT as a proportion of maximum possible output, 2015–2030



In the 'base case', load factors fall for both CCGT and coal in the next five years as renewables output increases. This decline is especially pronounced for coal, as the gas-to-coal price ratio falls to favour gas. However, in the early 2020s retirements of marginal CCGTs will allow remaining coal plant to increase production before being forced to close after 2025, putting coal's share of total generation over the next ten years at 7% (Chart 1.6). Notably, this scenario does not include a restriction on coal burn from 2023, which may become part of the coal phase-out policy. Without this coal closure policy, IED opt-in coal plants would sustain profitable levels of production throughout the 2020s, highlighting the instrumentality of such a policy in curbing coal burn and CO_2 emissions in GB power. When coal does close, CCGT output increases by nearly 40%, but most of this is a result of increased CCGT capacity on the system rather than higher load factors.

Chart 1.6. Electricity production by source, 2016–2025



In the 'low stress' scenario, load factors for coal and CCGT are very similar to the 'base case' over the next five years. The outlook for coal in the first half of the 2020s, however, is relatively less positive, as even retirements of existing CCGT will not be enough to stimulate coal-fired generation in a high-renewables, low-demand environment. Hence, it remains well below 10TWh/year from 2019 until coal is forced to close in 2025, putting coal's share of total generation in the next ten years at 4%. When coal does close, it only serves to momentarily halt the decline in CCGT output, which then continues to fall as CCGTs are squeezed out by renewables, nuclear and interconnectors.

The 'high stress' scenario sees the highest CCGT output by far, as coal is forced off the system after 2020, leaving a large gap behind. CCGT output remains at 120–130TWh/year until 2025, at which point significant new build enters and total CCGT output starts increasing and eventually exceeds 160TWh/year. The slow but steady increase in the first ten years puts CCGT's share of total generation at nearly 40%, in contrast to 32% in 'base case'. Notably, this increase comes both from new build plant and existing CCGTs extending their life and increasing their load factors. Together, these life extensions and increased utilisation of existing CCGTs make up for 46% of the lost generation from coal in the first half the 2020s.

Chart 1.7. Electricity production from coal and CCGT, 2015–2030

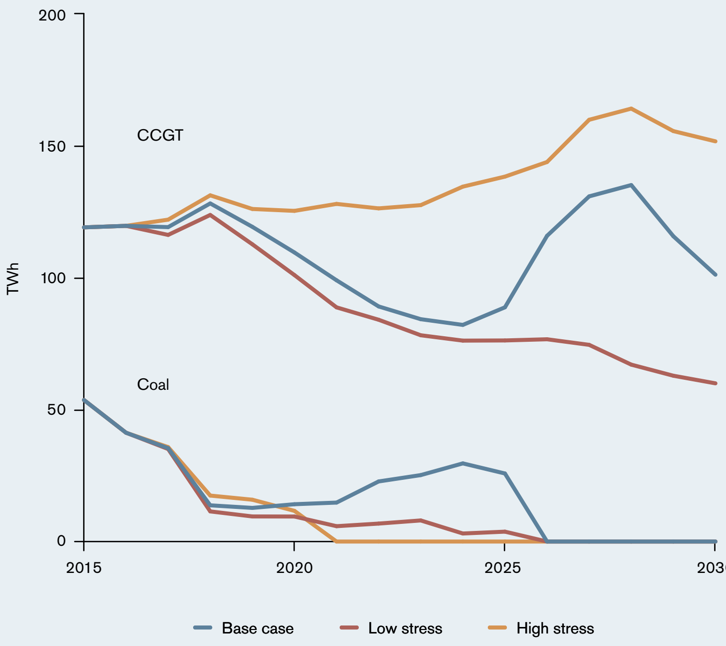
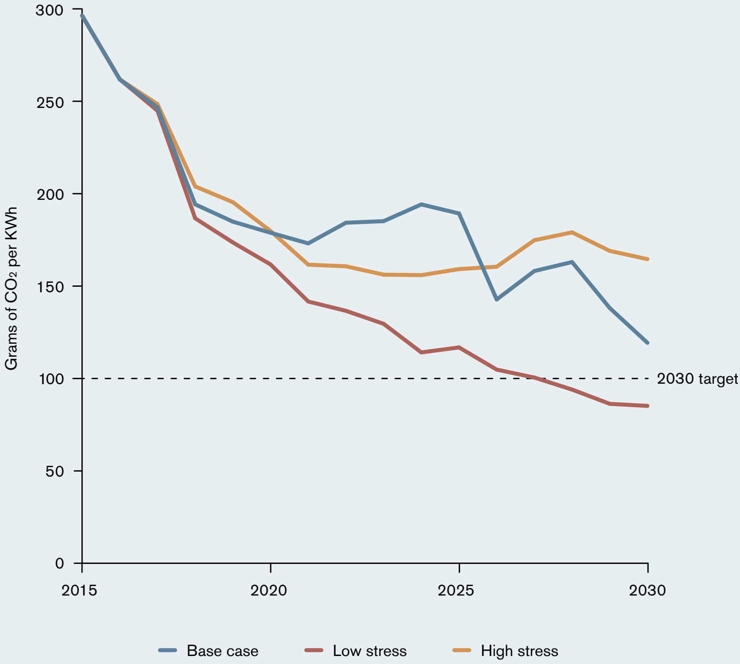


Chart 1.8. CO_2 intensity of GB electricity generation, 2015–2030



CO_2 emissions

Given that the CO_2 intensity of coal-fired electricity generation is significantly higher than that of gas-fired generation, a switch from coal to gas can be an important step towards meeting emission targets. Specifically, the Government's stated ambition is to reduce the average CO_2 intensity of GB electricity generation below 100gCO_2/kWh by 2030, which is highly unlikely to be realised if the coal fleet remains operational throughout the 2020s.

In the 'base case', the average carbon intensity of domestic generation falls steadily in the next five years as renewables output increases and several coal plants close. However, in the first half of the 2020s, increased generation by remaining coal plant fills the gap left by retiring CCGTs, and the CO_2 intensity of the system as a whole increases in the 2021–2025 period. Only when 7GW of coal plant retires at the end of 2025 does the CO_2 intensity start falling again. As illustrated in Chart 1.8, the system CO_2 intensity approaches 100gCO_2/kWh in the late 2020s, but without reaching it.

In the 'low stress' scenario, just like in the 'base case', total CO_2 intensity falls steadily in the 2016–2020 period. In contrast to the 'base case', however, this decline continues uninterrupted into the 2020s as there is no need for coal to increase generation when existing CCGTs retire. A combination of lower demand, higher output from renewables and more interconnection allow for adequate generation without coal. At this steady rate of decline, the Government's target CO_2 intensity for 2030 is well within reach.

In the 'high stress' scenario, the CO_2 intensity falls steadily until the early 2020s, but at a slower rate than the other two scenarios, principally due to higher total electricity consumption. With a stagnating build-out of zero-carbon generation capacity as well as interconnection, the CCGT fleet must both grow and increase production, completely halting and even reversing the decline in CO_2 intensity in the mid-2020s. The Government's target is not met and is exceeded by more than 50%.

Conclusion and implications

Aurora's analysis has shown that if coal is to be phased out in the 2020s, additional gas-fired capacity must be built to ensure security of supply. However, the quantities needed in the next ten years are not of a magnitude that should cause concern for the future energy security of GB. A switch to gas could be enabled by a combination of new-build gas plant entering in the 2020s and existing gas plant ramping up production.

- **Closing coal will not cause a security of supply crisis.** Unless there is a policy intervention to limit coal-fired generation, there are plausible market outturns in which 5–7GW of coal would continue to operate at high load factors throughout the 2020s. It would therefore require 2–6GW of new gas-fired generation capacity to be built in the 2016–2025 period, in addition to what has already been procured through the first two T-4 capacity auctions. In the most extreme outcomes, as little as 3GW and as much as 15GW could be needed in the

2026–2030 period. Put in historical context, the required quantities are comparable to the 10GW of new gas plant that were constructed during both the 1996–2000 and the 2010–2014 periods, and therefore appear challenging but feasible.

- **Coal will be replaced by a combination of new and existing gas plant.** In the year directly following the closure of coal, approximately 5GW of new gas plant will be needed in all scenarios. This is less than the retiring coal capacity due both to higher expected load factors for new-build gas, and to life extensions and increased utilisation of existing gas plant. Existing CCGTs could make up for as much as 46% of the lost generation from coal, hence limiting the amount of extra new build needed. Build-out of other technologies can also help replace coal. Policies and market conditions that stimulate renewables, nuclear and interconnection, and depress electricity demand, can significantly reduce the amount of new-build gas needed.

- **The timing of new build requirements depends on the market's response to the proposed policy.** If coal does not close before 2025, very little new-build gas will be needed in the next ten years, beyond what has already been procured through the capacity market. However, policy pessimism or weak market conditions for thermal generation might mean that coal closes even earlier than 2025, bringing forward some of the new-build requirements to the early 2020s.

Appendix: Technical assumptions

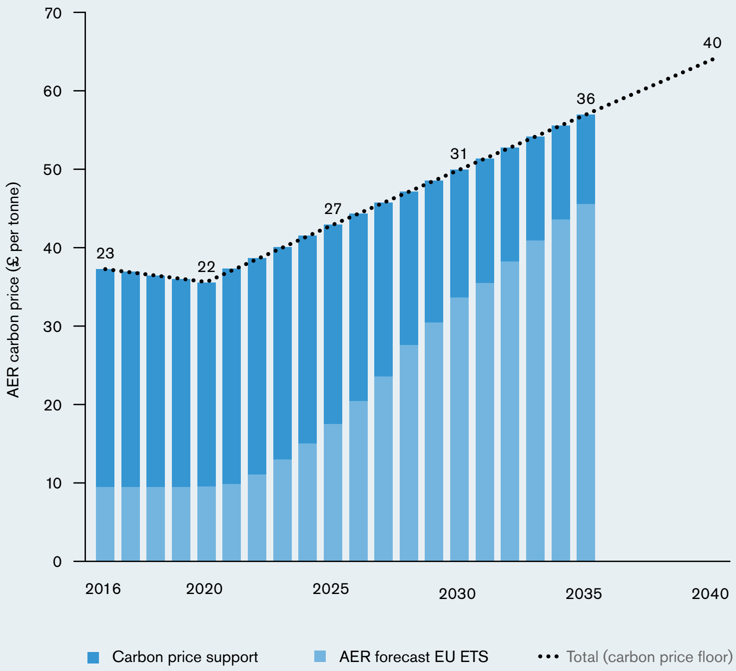
Aurora's models

The analysis done for this report is underpinned by the Aurora Energy Research Electricity System model ('AER-ES') which was independently developed by Aurora Energy Research. It is a market-leading dispatch model used by many of the major private and public sector participants in the GB and European power markets to address strategy, policy and finance issues.

AER-ES GB is a dynamic dispatch model built for the emulation of the GB power sector in half-hourly granularity. The model contains a fully specified Capacity Market module that iteratively finds the economically consistent capacity contract allocations throughout the coming decades, and the Capacity Market prices needed to trigger the required investments in generation capacity, subject to an exogenously given level of supply security.

The assumptions that underpin the analysis presented in this report are, unless otherwise specified, consistent with Aurora's quarterly Power Market Forecast for the GB market (January 2016). [27]

Chart 1.9. Carbon price, 2016–2040



27 For a detailed and exhaustive overview of these assumptions, please get in touch with Aurora at sales@auroraer.com to obtain a copy of the latest forecast report.

Carbon price assumptions

Assumption 1. GB carbon price trajectory. In our modelling, we assume that the Carbon Price Support ('CPS') freeze will last until 2019–2020, as currently legislated. Beyond 2020 we assume that the CPS will be adjusted year-by-year so as to achieve the government's target carbon price trajectory (Carbon Price Floor – 'CPF'), taking into account the evolution of the European price of carbon – the EU ETS allowance ('EUA'). During this period, we assume the carbon price trajectory to rise from the level of £22/tonne in 2020 to £40/tonne in 2040.[28]

Chart 1.9 summarises our carbon price assumptions. With weak EUA prices, and the UK's ambition to lead the EU's decarbonisation effort, we forecast a policy-driven GB carbon price that is above the price of European emission allowances. However, we also disaggregate our overall carbon price into EUA and CPS outlooks and report our official EUA forecast separately (see below).

Assumption 2. EU ETS allowance price trajectory. In our modelling of the EUA prices, we account for recent policy developments, including 2030 targets for decarbonisation, renewables deployment and efficiency improvements, as well as the tightening of emission caps under Phase IV of the ETS, and the introduction of the Market Stability Reserve.

To produce our internal EUA forecast, we employ a hybrid modelling approach that links our European power dispatch model AER-ES EU and our global general equilibrium model AER-GLO. The hybrid model solves for the price of carbon required to achieve a given carbon emissions cap in each year. The combination of a general equilibrium model that captures all economic activity, and a power dispatch model, captures the detailed mechanics of fuel substitution in the power sector at an hourly resolution, which is of critical importance for the carbon price trajectory.[29]

Broadly, our ETS forecast is based on modelling the carbon price required to reach the 2030 EU emissions target (40% carbon reduction relative to 1990 levels) in combination with other carbon reduction policies.

28 We do not specify the measure of these values contributed by the CPS, as we assume that it is adjusted accordingly in order to adhere to these targets. Our implicit assumption is that the EUAs prices do not exceed this trajectory.

29 For details on this approach, please refer to the Appendix of our report *Coal-to-gas switching in Europe: Policy levers, winners and losers, global impact* (Aurora Energy Research, 2015).

First, to establish a benchmark, we model the carbon price that would result if it were the only policy instrument employed in the ETS sectors to reach the 2030 target.

Second, we assume non-price policies (most notably mandated coal closures, efficiency standards and renewable subsidies) to share the load of carbon reductions, as practised in recent years by the EU member states. This lowers the ETS price required for the 2030 target.

Third, due to uncertainty in the contribution from non-price policies within the ETS sectors, we allow the EU to breach its cap by 1–2% in 2030. Based on our research and market consultations, we view this as a more realistic outcome than a very steep increase in the carbon price in the late 2020s.

Fourth, post-2030, we assume emission caps continue decreasing at the Phase IV pace of 2.2% per annum, with efficiency improvements and renewable deployment achieving their pre-2030 rate.

The resulting ETS allowance price forecast is broadly flat until 2020, before increasing steeply during Phase IV, reaching €29/tCO_2 in 2030, and €39/tCO_2 in 2035. We expect relatively little impact from 'back-loading' in Phase III of the EU-ETS – the postponement of the auction of 900 million allowances until 2019–2020.

Fuel prices assumptions

Fuel prices are the single most important driver of electricity market outcomes. Accurate forecasts for trends in fuel prices are therefore of paramount importance for electricity market modelling.

The Global Energy Markets Modelling team at Aurora produces regular baseline fuel prices forecasts, using our global general equilibrium model ('AER-GLO'). The model represents the economies of 129 countries, each broken down into 57 sectors. By using a general equilibrium model, which describes the interactions between sectors and countries in great detail, we capture the structural evolution of the economy in response to changes in demand. A general equilibrium approach offers a substantial advantage over partial equilibrium approaches, which tend to rely on exogenous growth patterns, locking the structure of the economy into past trends. On the supply side, we adopt a detailed dynamic resource extraction module, which is calibrated to our global extraction cost database.[30]

30 Aurora's long-term commodity price forecasts are explained in substantial detail in our annual *Global Energy Market Forecast* (Aurora Energy Research, 2015).

Chart 1.10. Natural gas price, 2016–2040

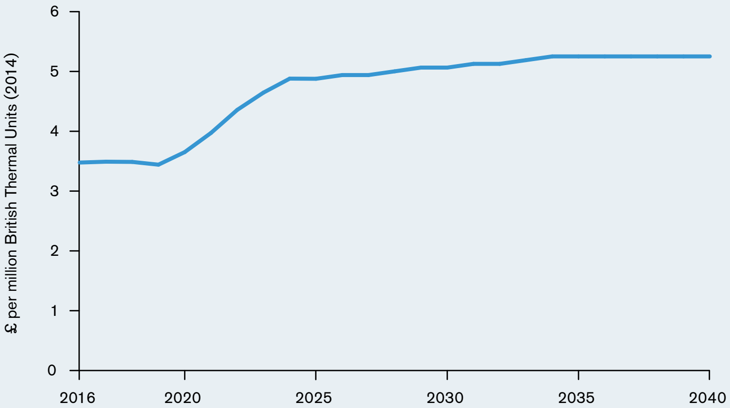
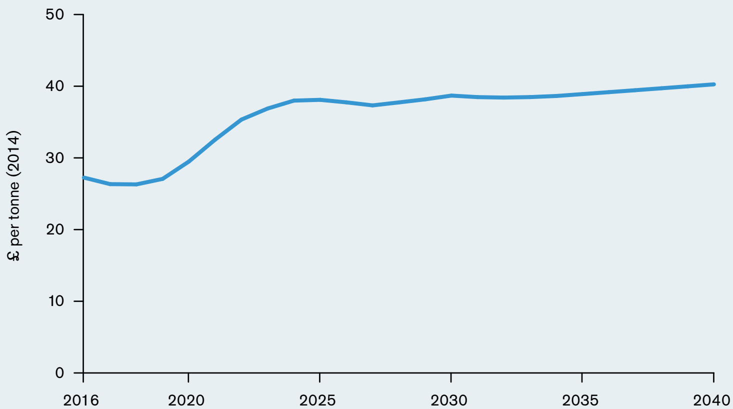


Chart 1.11. Coal price, 2015–2040



The fuel price forecast used for this report includes the following key projections (all in real 2014 terms):

The natural gas price in Europe remains broadly flat over the next ten years at an average level of £4.9/MMBtu, driven by steadily increasing global liquefied natural gas (LNG) availability mainly from the US and Australia; after that, prices return to their long-term upward trajectory, reaching £5.9/MMBtu by 2040. The upward trend is a result of the decline in quality of gas fields more than offsetting technological improvements in extraction – a historically observed relationship.

The coal price increases slightly over the next fifteen years and plateaus afterwards at long-term value of approximately £42/tonne; the initial increase is mainly driven by the return to Aurora's view on the current levelised cost of extraction. This follows a period of low prices caused by oversupply following China's demand boom and subsequent slowdown in consumption.

We use the gas and coal price forecast produced by AER-GLO throughout this report, which are illustrated in Charts 1.10 and 1.11. However, in the initial periods our assumed prices follow the latest available forward curves and over time converge to trajectories defined by the market fundamentals captured by AER-GLO.

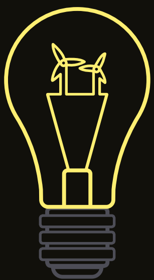
General disclaimer

Forward-looking statements

This document contains forward-looking statements and information, which reflect Aurora's current view with respect to future events and financial performance. When used in this document, the words 'believes', 'expects', 'plans', 'may', 'will', 'would', 'could', 'should', 'anticipates', 'estimates', 'project', 'intend' or 'outlook' or other variations of these words or other similar expressions are intended to identify forward-looking statements and information. Actual results may differ materially from the expectations expressed or implied in the forward-looking statements as a result of known and unknown risks and uncertainties. Known risks and uncertainties include but are not limited to: risks associated with commodity markets, technology, contractual risks, creditworthiness of customers, performance of suppliers and management of plant and personnel; risk associated with financial factors such as volatility in exchange rates, increases in interest rates, restrictions on access to capital, and swings in global financial markets; risks associated with domestic and foreign government regulation, including export controls and economic sanctions; and other risks, including litigation. The foregoing list of important factors is not exhaustive.

The Government has announced that it will phase out the use of coal in electricity generation by the mid-2020s, making the UK the first country to use coal for electricity generation and now the first developed country to phase it out completely. Since the announcement, however, there has been concern about the implications for the UK's energy security as coal is removed from the grid.

This report analyses the impact of the coal phase-out on the power system, the demand for gas, the UK's emissions targets and households bills. The lights will stay on. In fact, the report argues that it is feasible and desirable to phase out coal earlier than currently planned.



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